ELECTROMECHANICAL
components & systems DESIGN
8
JULY 1958

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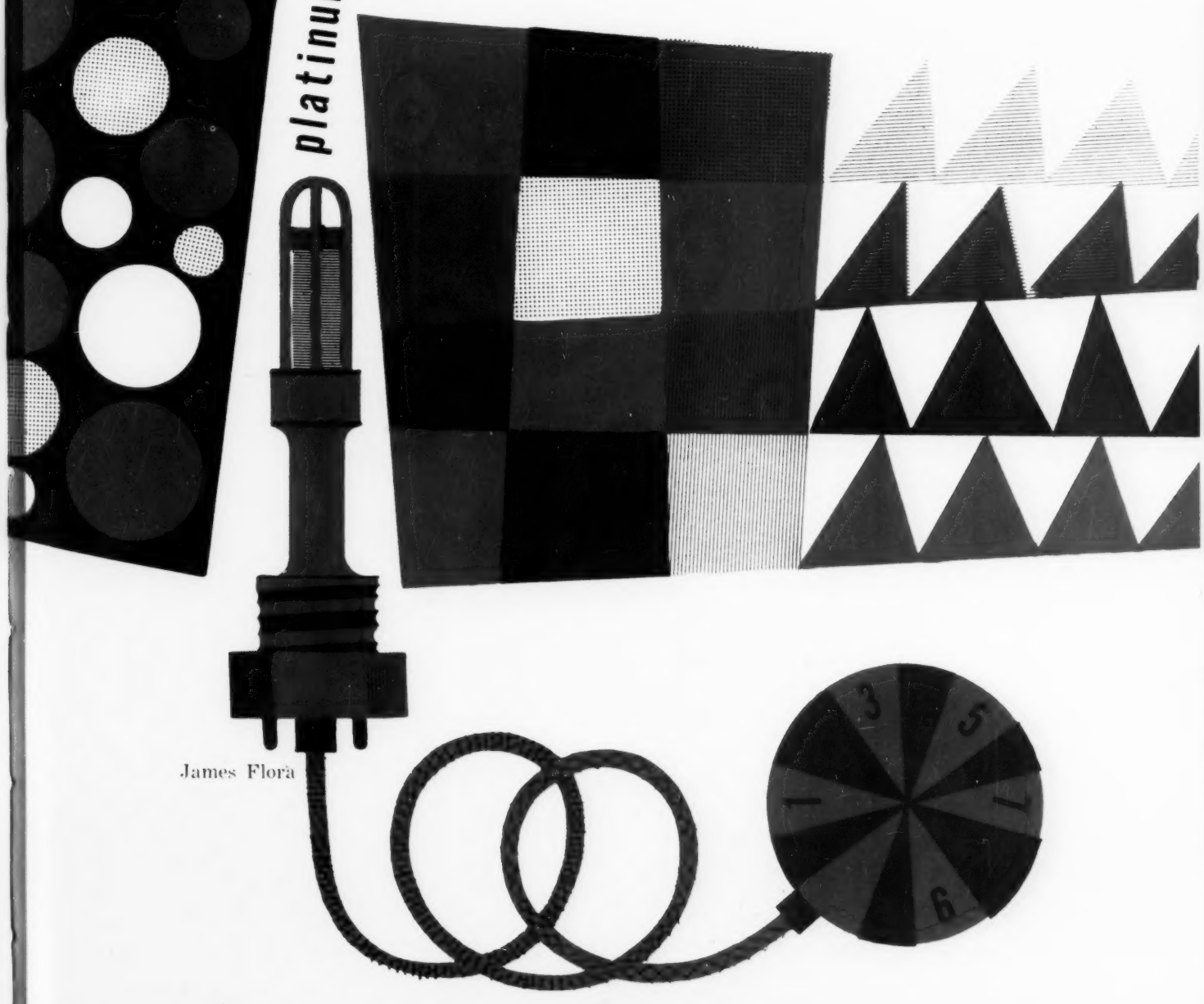
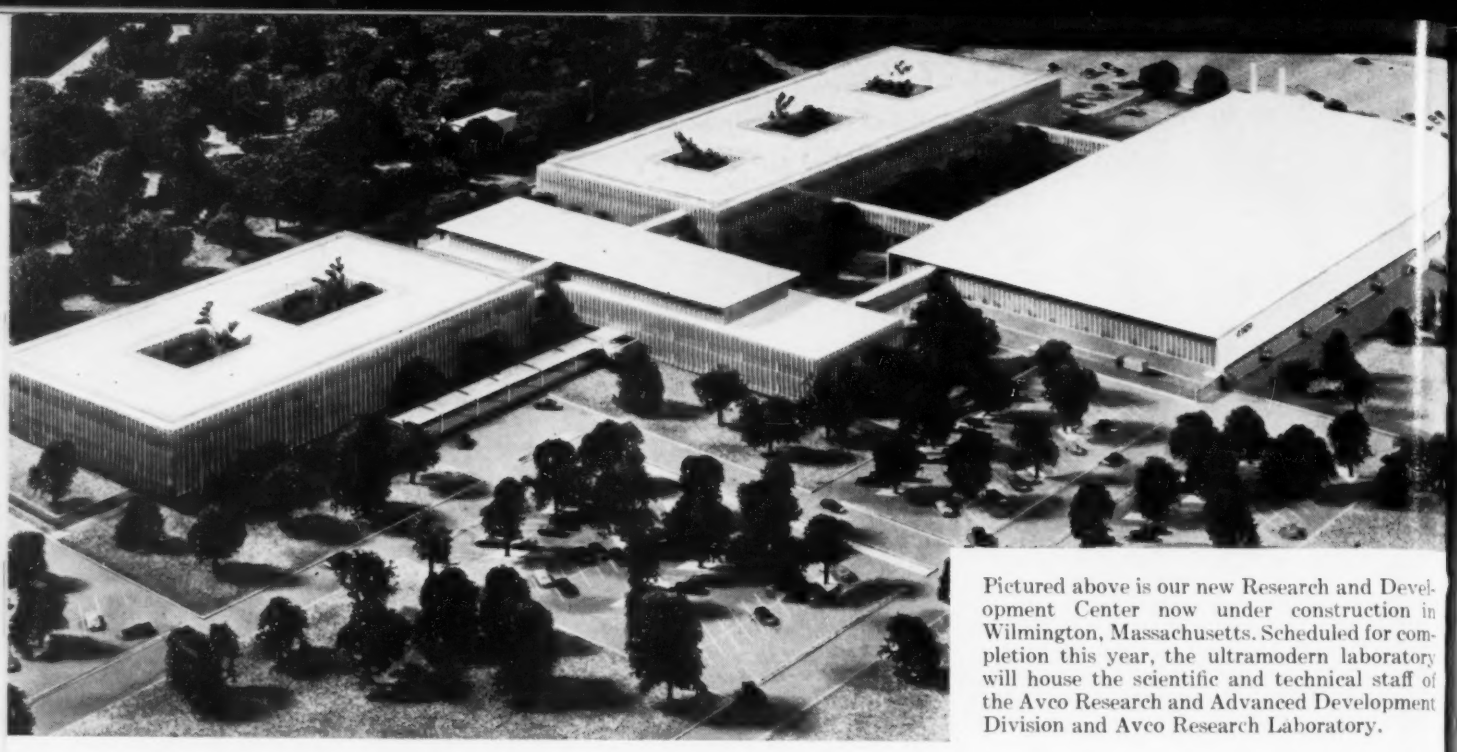
platinum resistance thermometers



James Flora



Pictured above is our new Research and Development Center now under construction in Wilmington, Massachusetts. Scheduled for completion this year, the ultramodern laboratory will house the scientific and technical staff of the Avco Research and Advanced Development Division and Avco Research Laboratory.

A Year of Science and Progress at Avco

Truly significant discoveries and technical progress are the goals of the Avco Research and Advanced Development Division. Some of the Avco RAD record of accomplishments are contained in professional papers in scientific and technical journals. Much of it is classified for reasons of military security. But the following public announcements serve to outline some of the steps taken by RAD—the "Breakthrough" Division of Avco—in pursuing its goal:

July 1, 1957.....Avco to Develop New Radio Pack Set for Marine Corps

July 2, 1957.....Prime $111 Million Contract Announced for Development by Avco of Nose Cone for Intercontinental Ballistic Missile

August 28, 1957.....Avco Shock Tube Research Has Produced Theoretical Breakthrough on 5000-Mile Air Force Ballistic Missile

November 23, 1957....Tiny "Building Blocks" Revolutionize Computer Design and Construction

December 17, 1957....Details of Successful Search for Nose Cone Shape Revealed

March 6, 1958.....Avco Markets Kerr Cell for .01 Microsecond Exposure

March 25, 1958.....Avco Develops 3000 wpm Tape Communication System

April 17, 1958.....Development of Unique Shock Test Machine for Missile Components

Avco's record during the past year is significant from scientific, technical and business points of view. It has been made possible by sustained effort at RAD to maintain an atmosphere conducive to creative thinking and production of the highest order.

AVCO

Research & Advanced Development

Avco's new research division now offers unusual and exciting career opportunities for exceptionally qualified and forward-looking scientists and engineers.

Write to Dr. R. W. Johnston, Scientific and Technical Relations, Avco Research and Advanced Development Division, 20 South Union Street, Lawrence, Massachusetts.

ELECTROMECHANICAL DESIGN 8

components & systems

JULY 1958
VOLUME 2 • NUMBER 6

The Sourcebook of Design Ideas and Techniques in Applied Electromechanics

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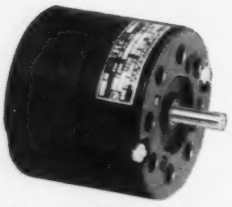
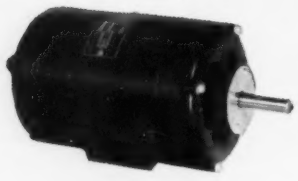
CIRCLE 1 ON INQUIRY CARD

EVERY HOUR

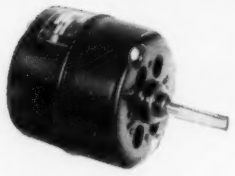
2 new applications are filled by HOWARD Fractional Horsepower Motors



Model 2800 Illustrated
Shaded Pole Motors
1/2000 to ⅛ H.P.



Model 2900 Illustrated
Induction Motors
1/1400 to ¼ H.P.



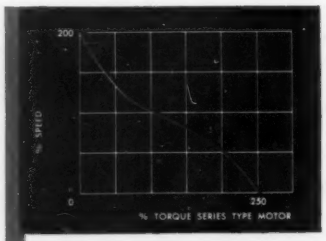
Model 11A Illustrated
Universal and D.C. Motors
1/100 to ½ H.P.

MORE THAN 100,000 FILLED SPECS ON FILE

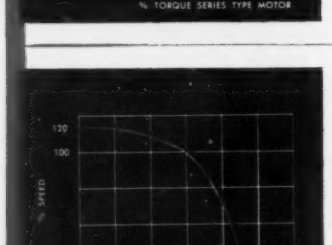
Through the years, designers and purchasing agents have learned that they can *depend* on Howard to *quickly* and *inexpensively* produce a motor to *any* specifications. With over 100,000 specs on file, chances are Howard engineers have worked on applications similar to yours—and can easily meet your mechanical, electrical and cost requirements. To aid you in selecting the right motor for a particular job, general characteristics of the basic Howard motor types are listed below. Whatever your needs, if you're in the market for power—check with Howard first.

CHARACTERISTICS AND TYPICAL SPEED TORQUE CURVES OF BASIC HOWARD FRACTIONAL HORSEPOWER MOTOR TYPES

UNIVERSAL MOTORS



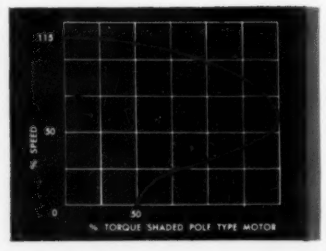
Series Type
Power: DC and AC 25 to 75 cycles.
1. High No Load Speed.
2. Full Load Speed (Optimum Performance) at approximately 50% no load.
3. Starting Torque high, 200 to 300% full load torque.
4. Variable speed, speed decreases with increasing loads.



Shunt Type **Power:** DC only.
1. No load and Full load speed are adjustable by winding or by armature and/or field voltage control. Approximately a 2:1 speed range can be obtained by field control, and 10:1 by armature control.
2. Fairly constant Full load speed.
3. Regulation varies from 10% to 30% depending upon duty and power requirements.
4. Starting torque, approximately 150 to 200% of Full Load.

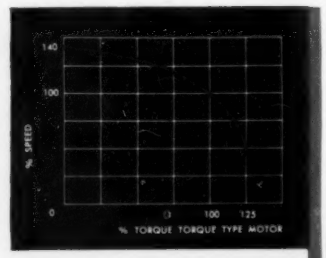
SHADED POLE MOTORS

Power: AC 50 to 60 cycles.
1. No load speed is determined by the number of poles with a No load slip of 3 to 5%.
2. Fairly constant Full Load Speed, with a full load slip of 10 to 20%.
3. Breakdown torque approximately 150% of full load.
4. Starting torque low, 50 to 75% of Full load.



INDUCTION MOTORS

Torque Type
Power: AC 50 to 60 cycles.
1. No load speed is determined by number of poles, with a No load slip of approximately 5%.
2. Full load speed decreases with an increasing load. Designed to operate at approximately 30% full load slip.
3. No breakdown torque.
4. Startina torque high approximately 125% full load.



Capacitor Run Type
Power: AC 50 to 60 cycle.
1. No Load speed is determined by the number of poles, with a No load slip of 2 to 4%.
2. Constant full load speed, with a full load slip of approximately 10%.

Hysteresis Synchronous type
Power: AC 50 to 60 cycles.
1. Constant synchronized speed, determined by number of poles.
2. Starting torque equal to full load torque.
3. Quiet operation.

Reluctance Synchronous type motor
Power: AC 50 to 60 cycles.
1. Runs at a synchronized speed, determined by the number of poles.
2. Starting torque low, 50 to 75% of full load.

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Other Howard motors: UNIVERSAL & D.C. 1/200 to 1 h.p. • SHADED POLE 1/2000 to 1/8 h.p. INDUCTION 1/1400 to 1/8 h.p. • SERVO MOTORS • GEAR MOTORS • BLOWERS

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Problems in Need of Solution

Each month our editorial pages emphasize new ideas and techniques in engineering germane to electromechanical research, development, design and the management of these functions. This month we are using this space to call your attention to four major unsolved problem areas within this field that need new and creative approaches.

Last month, Allen V. Astin, Director of NBS in a talk given at the 61st Annual Meeting of the ASTM pointed out that our technical proficiency is downright inadequate in:

(1) High temperature standards, instruments, measurement techniques and materials data. Need in this area is critical for continuing progress in high speed flight, highly energetic propulsion systems, guided and ballistic missile development, jet engines, atomic reactors, power plants and industrial high temperature production and products.

(2) High pressure instrumentation and measurement techniques. Industrial use of high pressure in product synthesis is increasing. Super high pressure techniques and equipment are critical needs for new material and product development.

(3) Direct force measurement techniques and equipment. We now have a demand in ballistic flight for calibration that will provide a certification of a one-million pound device to one tenth of a percent. Such calibration accuracies cannot as yet be provided.

(4) Ultra-high and microwave frequency measurement devices. NBS at its new Boulder Laboratories will be devoting its major effort to the development of new and improved radio standards in high frequency and microwave quantities, such as power, impedance, voltage, current attenuation, field strength and noise—some of the unresolved instrumentation problems in this area.

It is highly unlikely that instrumentation in these four major problem areas will be solved by purely electronic or purely mechanical means; more likely they will be solved by and with electromechanical devices, techniques and approaches. If any of you have made progress toward the solution of specific problems in these areas, we shall be happy to report them through the pages of ELECTROMECHANICAL DESIGN. Just drop us a line.

Robert B. Brotherston
EDITOR

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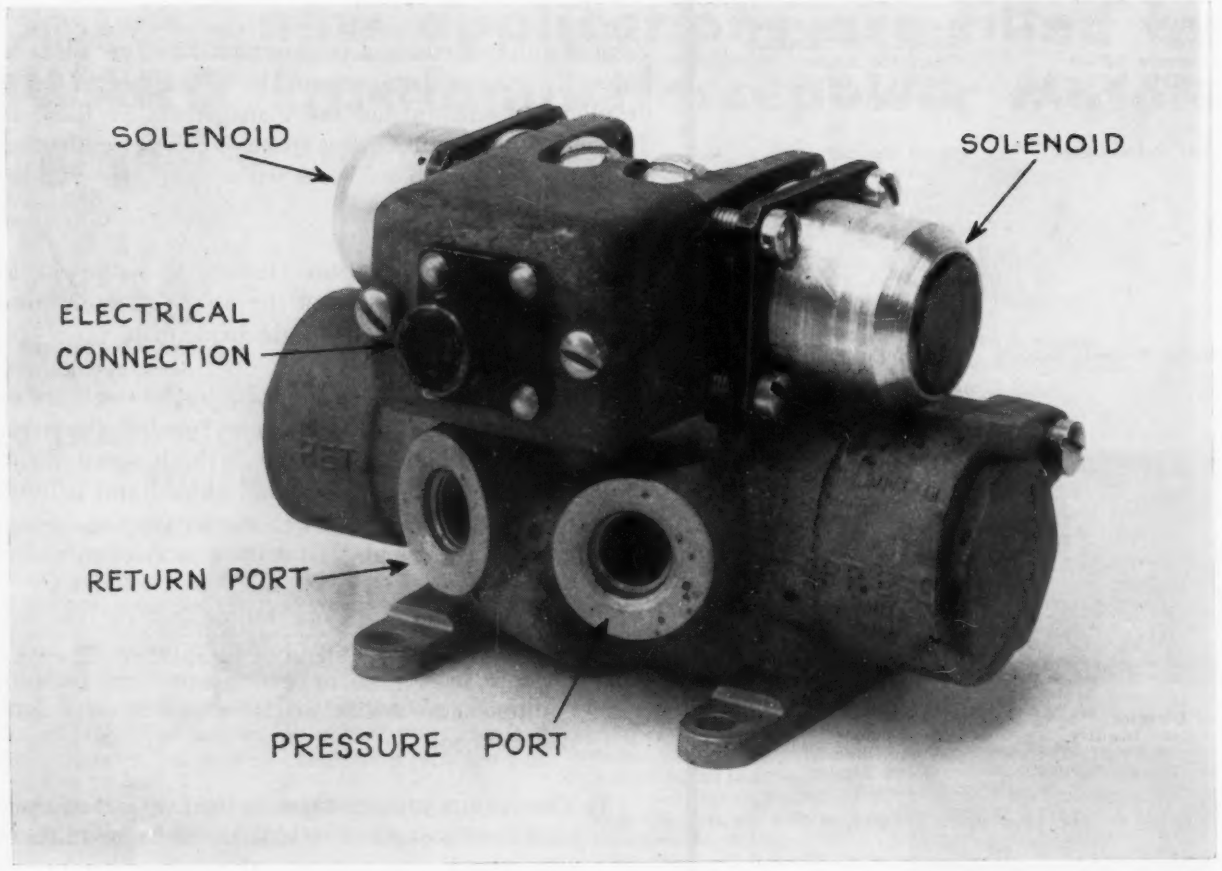


With Parker pilot-operated 4-way position valve the return force normally supplied by a hydraulic pressure of 300 to 350 pounds. Valve is designed in 3 and 4-way and 2 position configurations.

A-C POWER FOR AIRCRAFT

D-C Solenoid-Valve for A-C Systems

Aircraft manufacturers are rapidly shifting from d-c aircraft electrical systems to a-c systems which are lighter and have lower transmission losses. This shift has required extensive redesign of nearly every component used in aircraft electrical systems. The change has created a considerable problem in one area. Solenoids operate much more efficiently and reliably with d-c power than they do with a-c.

For example, according to Scott Hawkins, Northrop design engineer, "The T-38 has an a-c electrical system which saves a lot of weight, particularly on motor actuators. The only place where there is a penalty is on solenoid valves, which operate better on d-c."

PROBLEMS OF AN A-C SOLENOID

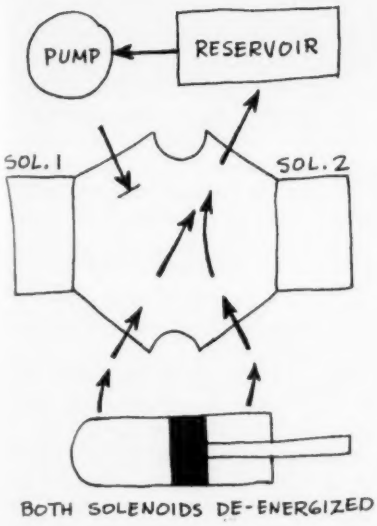
Problems in use of a-c solenoids were described to us by Will Margrave, Chief Engineer of the Hydraulics Division of Parker Aircraft Co., a subsidiary of Parker-Hannifin Corp., Los Angeles, California. To prevent high eddy currents, which are characteristic of solid cores, the solenoid must be laminated. Using a laminated core increases the time required for current to build up and increases retension when current is shut off. As a result action of an a-c solenoid is not as fast as that of a d-c solenoid. In addition, the amount of current that flows through an a-c solenoid varies with position of the moving core. When the actuator is in a position that results in a large air gap, current flow through the solenoid is very large, requiring heavy wires and reliable insulation.

"Moreover," Margrave pointed out, "many solenoid actuators are used in conjunction with a hydraulic control system, and many of these are now operating at pressues up to 3,000 psig. This high pressure increases force that must be developed by actuating a solenoid, which in turn further increases size and weight disadvantages of a-c solenoids. In fact, a-c solenoids designed for service with high pressure hydraulic systems must usually draw a narrow line between unwieldly size and danger of coil burnout."

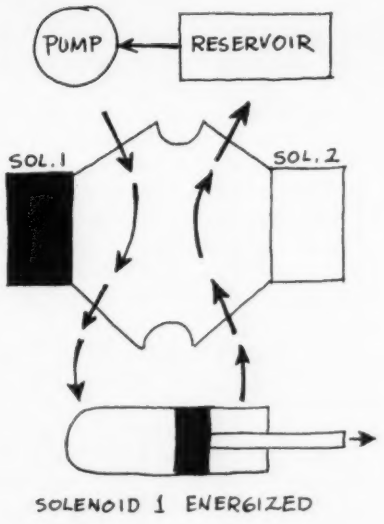
One solution would be to replace all solenoid actuated valves with either pneumatic or hydraulic actuators. "But this," Margrave said, "is rarely practical. In many cases, especially in spots remote from the engine, advantages of electrical actuators are critically important. Small electrical wires cannot easily be replaced by relatively large hydraulic or pneumatic lines with their inherently greater weight. Moreover, with electrical actuators, control can be accomplished directly from the cockpit with a switch. Usually, putting hydraulic or pneumatic control valves in the cockpit is not as feasible."

FROM AC TO DC

To resolve these difficulties, some aircraft designers have installed two electrical systems in their craft. They use an a-c system to power all motors and electronic elements, and a d-c system to connect all solenoid-activated control units.



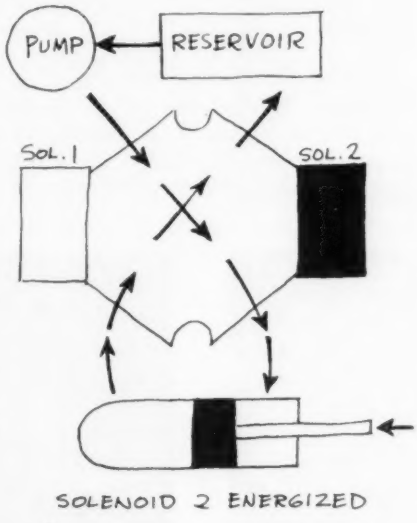
With both solenoids de-energized, reservoir pressure is fed to both sides of the actuator.



When solenoid 1 is energized the main valve spool moves to the left. Pump pressure is fed to the left side of the actuator forcing the actuator rod to the right.

This is obviously a makeshift solution, but it does point up a significance of a series of new solenoid valves designed by Parker Aircraft Co. By designing a solenoid-activated valve that in effect provides its own source of d-c power when connected to the aircraft's a-c power supply, the unit allows the control system designer to take full advantage of both types of electrical systems. A demodulating circuit within the valve unit converts the aircraft's a-c power to d-c, permitting the designer to incorporate the valve into an aircraft control system without having to provide a separate source of d-c power for the solenoid actuators.

The Parker valve uses a single-phase bridge circuit to rectify the a-c power supply. The rectifier consists of two identical sets of two silicon rectifiers rated at 400 volts ac. Weight savings obtained through the use of d-c solenoids compenate for the added weight of the rectifiers. As a result there is no weight penalty. The circuit is fully potted in mastic so that it can withstand severe vibrations.



When solenoid 2 is energized the main valve spool moves to the right. Pump pressure is fed to the right side of the actuator forcing the actuator rod to the left.

PILOT OPERATED

Parker's a-c solenoid valves are pilot operated. Pressure of fluid being handled actually opens the valve. Full power actuation is used instead of the spring return usually used in valves of this type. Instead of 15 to 25 pounds of return force, supplied by a spring, a hydraulic force of 300 to 350 pounds returns the spool in a 3000 psi system. In spring return valves, spring forces must be large enough to return the spool under maximum system pressure, but springs with forces of 300 to 350 pounds would be excessively large and heavy.

Designed to operate over a range of pressures from 250 to 3000 psi, the valve has a burst pressure of 7500 psi. Fluid service is hydraulic oil which can be handled over the temperature range of 65° to 275°F. (Class II hydraulic system requirements). Over the entire range of temperatures, the valve will change position in less than 0.25 seconds. During the operating time the flow goes from ½ to 4 gpm and the pressure from 0 to 3000 psi.

Circle No. 136 on Inquiry Card

ELECTRICAL ENGINEER'S GUIDE TO INSULATED wire

subject: APPLIANCE WIRE

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conductors: copper; nickel; nickel clad copper; nickel plated iron; aluminized iron.

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CIRCLE NO. 12 ON INQUIRY CARD

COMPONENTS DESIGN

VARIABLE REACTANCE MICROWAVE AMPLIFIERS

Semiconductor Diodes Reduce Noise

Noise is a major problem in the amplification of weak microwave signals. Commercially available amplifiers and converters add a considerable amount of noise to the incoming signal, thus decreasing the sensitivity of the receiving equipment. A major reduction in this added noise can significantly improve the performance of radio receivers such as those used in radar, radio astronomy, over-the-horizon radio relay and uhf television systems. A new diode amplifier, under development at Bell Telephone Laboratories, holds promise of providing such a noise reduction, is said to be relatively simple to construct and operate, and shows prospects of having a long life.

This amplifier is one of a family of devices known as variable reactance amplifiers in which a variable reactance, or "varactor", serves as the active component. In the present device, the variable reactance is provided by a semiconductor diode (varactor diode) whose capacitance varies with the applied voltage. As with the other varactor amplifiers, the applied voltage is derived from a high-frequency pump signal. This signal causes the diode to function as a time-varying capacitance and supplies the energy necessary to produce amplification. Low-noise amplification using varactor diodes was predicted by A. Uhlir, Jr. of Bell Laboratories.

A traveling-wave amplifier configuration using arrays of several diodes is said to show promise of providing bandwidths of 25 percent or more in the uhf region. Using four stages with the special diodes in such an array, R. S. Engelbrecht of Bell Laboratories has obtained a bandwidth of 100 megacycles at a 400-megacycle signal frequency, with a pump frequency of 900 megacycles and a pump power of 10 milliwatts. This experimental amplifier has a gain of 10 db and a noise figure of only 3½ db.

A single type of diode can be used to make an amplifier for any desired frequency from the high microwave region down to dc. The noise performance improves rapidly as the frequency decreases from microwaves down into the uhf region, thus making such an amplifier potentially useful for uhf television receivers.

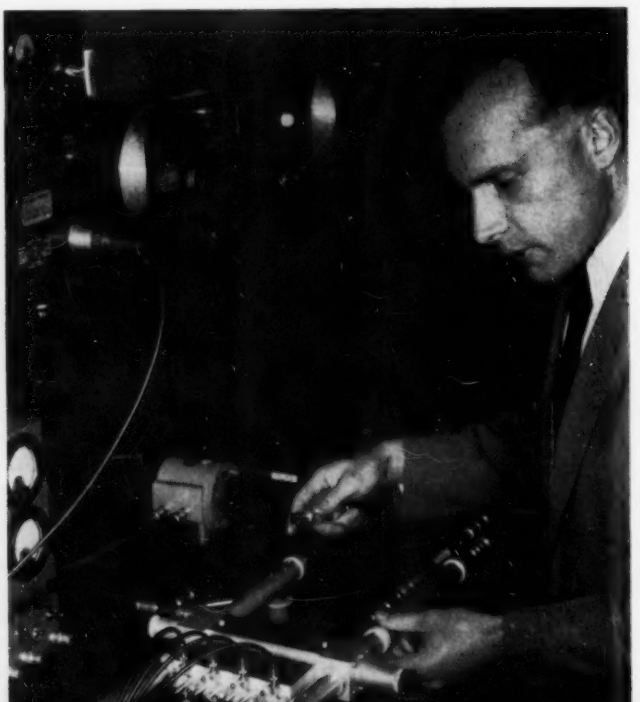
Interesting aspects of the diode amplifier are its simplicity and potential reliability. Major components are the proper waveguide structures, the diode itself, and a suitable pump signal source. It appears that these components can be assembled to provide a relatively inexpensive device. No refrigeration is required, and no magnetic fields are necessary. The low-noise characteristics are realizable at room temperatures.

Although the variable capacity effect is present in commercial diodes, Bell Laboratories' scientists have developed, under a Signal Corps contract, special diffused silicon diodes to maximize this effect. Series resistance, which could be a source of noise, is minimized in these diodes. Units fabricated by N. G. Cranna of the Laboratories have an active diameter of about 0.002 inch.

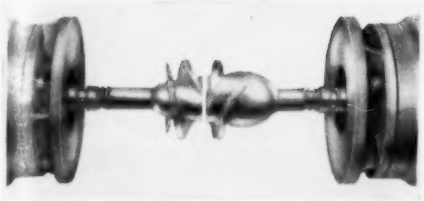
The development of the varactor diode amplifier holds promise of providing a whole new family of low-noise amplifiers for the uhf and microwave frequency ranges. These devices will complement the semiconductor diode up-converters recently announced by Bell Laboratories, which can also provide low-noise amplification.

Circle No. 214 on Inquiry Card

Equipment for studying the amplifying properties of a nonlinear capacitor semiconductor diode. The right hand is holding the special diode and enclosure, and is about to insert it in the proper location in the waveguide structure. A pump frequency of 12,000 megacycles enters from the left. The signal, in this case 6,000 megacycles, comes in from the right, is amplified and reflected back inside the same waveguide. The incoming and outgoing signals may be separated by a ferrite microwave circulator.



R. S. Engelbrecht of Bell Telephone Laboratories is assembling equipment for testing a type of traveling wave amplifier employing four stages with special amplifying diodes.



Counter-rotating Pump

Unique counter-rotating pump specifically designed to handle problem materials with unusual efficiency handles chemical slurries, soaps, pulps, sand and water, pastes, and viscous materials in a wide range of densities, with solid particles in suspension, at very low and very high temperatures, and at high flow rates and pressures, without separation of the mixtures. The exceptional efficiency of the small pump is accomplished by use of a patented method of counter-rotation supplied by two small-diameter impellers. These axial impellers, of unique double-Venturi design, counter-rotate at relatively high velocities, and allow free passage of coarse and viscous material.

The Baez pump is simply designed, with open clearances throughout. No sealing or wearing rings are required and two identical volutes, one for suction and one for discharge, are arranged on either side of the centrally located impellers. The housings of the volutes can be rotated, permitting pipe connections to be vertical or horizontal and face in any direction. Double teflon and carbon shaft seals are used.

The material to be pumped is drawed into the suction volute by the suction impeller or inducer driven by the first motor, and ejected into the second impeller or educer driven in the opposite direction by the sceond motor. The helix on the educer is of the opposite hand to that of the inducer and gives unidirectional axial flow from suction to discharge. The high relative velocities of the counter-rotating impellers enable the rotors to be made small and compact and still provide great heads.

Baez Counter-Rotating Pump Corporation,
Port Washington, L. I., New York

Circle No. 171 on Inquiry Card

Silicon High Q Variable Capacitor

Miniature Silicon variable capacitor with Q of 1000+ at 1 megacycle and a 10 to 1 capacity ratio within its peak inverse voltage rating of −200 volts d.c. can replace conventional mechanical capacitors and other variable reactance elements. Tradenamed Semicap, its high reliability and low power requirements make it ideal for automatic frequency control, frequency modulation oscillators, and filter networks where precision capacitance control is an essential design parameter. International Rectifier Corporation, EL Segundo, Calif.

Circle No. 167 on Inquiry Card

High Performance Multicoupler

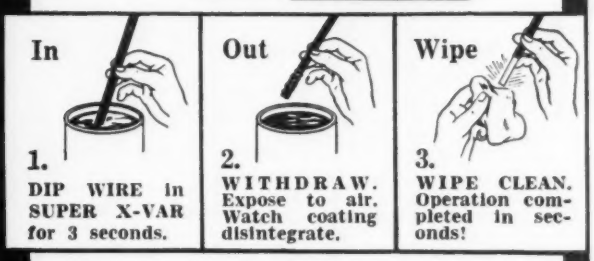
Designed to couple one antenna to 10 receivers operating anywhere between 2 and 32 mc/s, the new TRAK Model 21 Multicoupler features 60 db isolation between outputs, 60 db attenuation of intermodulation components, and a 6 db noise figure. Unique modular isolator circuits attenuate receiver local oscillator signal by more than 90 db between receiver and antenna. Degradation of weak signals by a 1-volt signal is limited to 1 db over the band. Maintenance is simplified with repetitive circuitry, use of only one tube type throughout, and ready access to all components. Illustrated literature available. CGS Laboratories, Inc., Ridgefield, Conn.

Circle No. 53 on Inquiry Card

NEW! REVOLUTIONARY!

SUPER X-VAR

Removes "Hard-to-Strip"
FORMVAR, FORMEX, & ENAMEL
insulation In Seconds!



1. DIP WIRE in SUPER X-VAR for 3 seconds.

2. WITHDRAW. Expose to air. Watch coating disintegrate.

3. WIPE CLEAN. Operation completed in seconds!

New Super X-Var quickly removes coatings that X-Var can't remove or removes slowly. Non-corrosive and leaves wire ready for soldering. Now in use by leading manufacturers of electrical products.

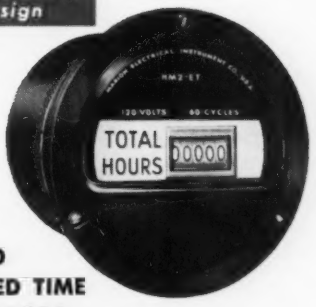
Request free sample for test use.

Fidelity Chemical Products Corp.
476 Frelinghuysen Ave., Newark 5, N. J.

International Division
15 Moore St., N.Y.C. • Cable "CHURCHIN" New York

FOR MORE INFORMATION CIRCLE 16 ON INQUIRY CARD

marion
advancement in instrument design



SEALED ELAPSED TIME INDICATORS

SCHEDULE MAINTENANCE — STUDY PRODUCTIVITY

Glass-to-metal sealed ELAPSED TIME indicators. Compact, low cost, tamper-proof. Standard ASA/MIL dimensions, 2½" and 3½" sizes. Easy to read standard size counter registers 1/10 hour steps to 9999.9 or hour steps to 99999. Hermetically sealed. Shielded. Starts, operates continuously from −55°C to +85°C. For 110-125 or 220-250 volts 60 cycle A.C. Bulletin on request. Marion Electrical Instrument Co., Manchester, N. H., U. S. A.

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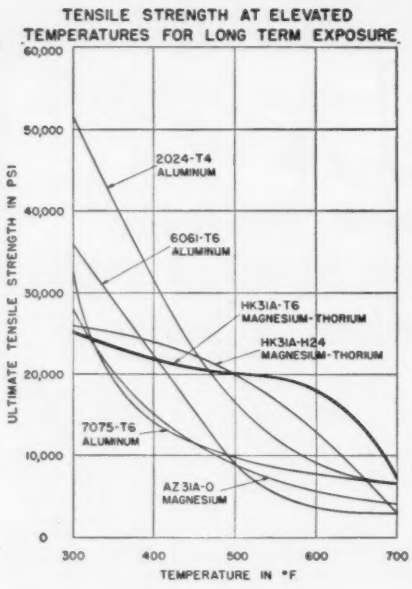
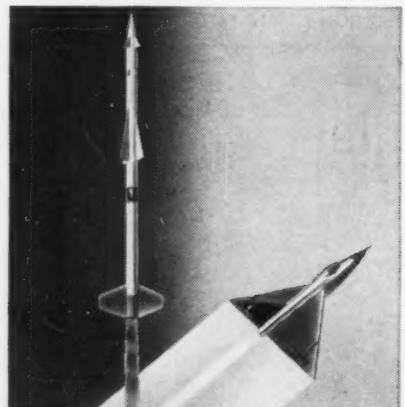
marion meters
"WHERE ELECTRONICS MEETS THE EYE"

FOR MORE INFORMATION CIRCLE 17 ON INQUIRY CARD



Creep Resistance at 300°-700° F.

In this temperature range, use the thorium-containing alloys of magnesium. They are the only satisfactory metals which combine creep resistance with good strength and light weight.



For designers of high speed jet planes, rockets, and guided missiles, this solves a problem. Formerly it was thought necessary to use heavy materials. They are less satisfactory than these magnesium alloys.

Formerly available in the form of castings only, thorium-containing magnesium alloys now come in rolled sheet. B&P's mill produces this sheet.

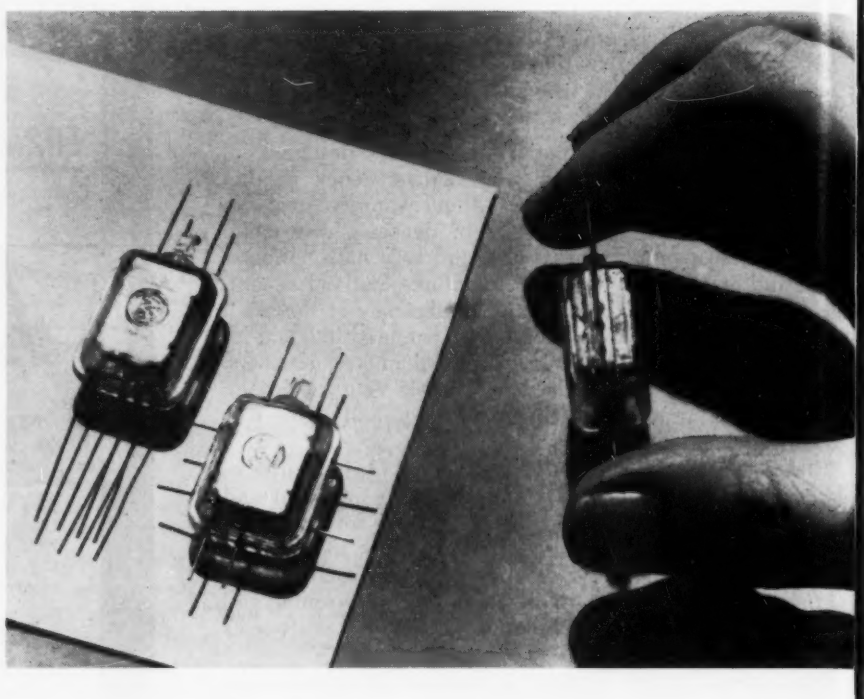
B&P engineers will help you redesign in magnesium. B&P offers the magnesium industry's most complete facilities for fabrication and assembly. Your inquiry will bring a descriptive booklet. D-3

BROOKS & PERKINS, Inc.

LIGHTNESS . . . PLUS!

1970 WEST FORT STREET
DETROIT 16, MICH.

CIRCLE 5 ON INQUIRY CARD



RECEIVING TUBE

Match-Box Design Improves Circuit Performance

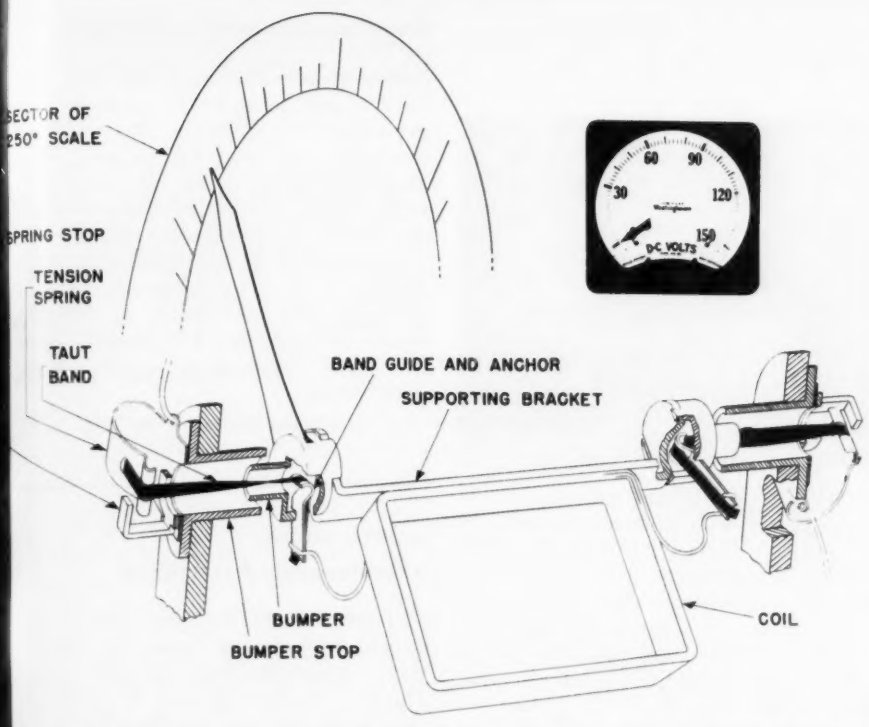
A new type of envelope, called the "match box" design, applicable to a complete line of receiving tubes and using the same electrode structure as conventionally designed receiving tubes has been developed by the Westinghouse Electric Corporation, Electronic Tube Division, Elmira, N.Y.

Dr. W. H. McCurdy, manager of applied research, stated that although this design has future commercial application, development efforts have been concentrated on fulfilling the needs of the military. The new envelope configuration improves circuit performance and reliability beyond that possible with conventional tubes. Design details that make the improvement possible are:

- Elimination of the tube stem permits all lead welds to the mount structure to be in one plane making the welds more accessible and subject to control.
- Envelope shape permits greater flexibility for the tube designer and equipment designer. For instance, the high-dimensional accuracy of the "match box" tube envelope, and the protrusions for locating the mica spacers permit the elimination of the mica serrations, thus removing the danger due to loose particles and gas.
- Since the mount structure is locked within the envelope, microphonism and resistance towards severe vibration and shock is greatly improved.
- "Match box" tube also leads itself to recessing or strapping onto the printed circuit board. If desirable, the straps can serve as an effective heat sink.
- Mechanized feeding to printed circuit boards and chassis is now possible because of the rectangular shape of the new family of receiving tubes. If high-temperature envelope material is used the size of the new tubes can be reduced. The "match box" tube improves the form factor of the sub-assemblies (modules) and reduces the space required. Elimination of the tube reduces noise and circuit capacitance.
- Larger lead spacing is also now possible. Input and output leads can be placed further apart minimizing pickup or feedback and allowing simpler and more reliable soldering. Lead arrangement can be designed to better fit the circuit. The diameter of lead wire ranges from 0.020 to 0.028 inches. Copper-clad lead-in wires are used which assures satisfactory ultrahigh frequency performance.

Westinghouse reports that preliminary investigation has shown that the new "match box" tube design is resistant to the destructive effects of atomic radiation. More study is being carried out in this field to determine the exact amount of radiation that can be tolerated.

Circle No. 186 on Inquiry Card



Essentials of construction of new Westinghouse instrument line in which hair-like metal bands under tension support the moving element, carry current to the coil, and supply restoring torque. New 250-degree d-c switchboard instruments using this construction are proof against severe vibration and shock. No pivots or bearings are required and rolling and sliding friction are eliminated.

SWITCHBOARD INSTRUMENTS

Taut Band Suspension Eliminates All Rolling, Sliding Friction

A unique taut band suspension system for circular-scale switchboard instruments uses no pivots or bearings and is completely free of rolling or sliding friction. The only frictional loss is an infinitesimal amount of molecular friction within the taut metal bands.

This new development makes it possible to build electrical measuring instruments that can withstand severe vibration and shock without any effect on their accuracy.

According to A. J. Petzinger, manager of the Westinghouse Instrument Department, the new Westinghouse instrument line is the first application in the United States of taut band suspension to instruments for general industrial service, and the first application in the world to 250-degree instruments. In instruments with taut band suspension the moving element is supported at each end by a short hair-like band of a special Westinghouse high-strength alloy drawn to rectangular cross section. Measuring 0.005000 inches wide and 0.000500 inches thick, the bands are dimensionally controlled to less than five millionths of an inch.

The bands are permanently anchored to the moving element of an instrument and to U-shaped springs which maintain proper band tension and contribute to immunity to shock and vibration. Small stops prevent excessive axial and radial movement as a further measure for shock-proofing. In addition to serving as the "axle" for an instrument, the taut bands also carry current to the moving coil and, by providing restoring torque, eliminate the need for spiral springs. In instruments built with taut band construction, sensitivity of an unusual degree is inherent. Full-scale 250-degree deflection can be obtained with currents as low as 50 microamperes.

The new instruments include direct-current ammeters, milliammeters and microammeters, and voltmeters and millivoltmeters. Frequency meters with transducers and a-c voltmeters of the rectifier type are also included. They all meet or exceed requirements of ASA Specification C39.1 for indicating instruments.

In addition to taut band suspension, the instruments also have a new magnetic circuit that makes them practically impervious to stray magnetic fields. Specifically when subjected to a 300-gauss field instrument indication will be affected by no more than one percent.

Production of the new instruments has already begun at the Westinghouse instrument department in Newark, N.J.

Circle No. 213 on Inquiry Card

MISSILE ENGINEERING

The "collapsing of time" concept has taken on added significance as a result of the current international situation. In Tucson, Arizona, Hughes has established the Tucson Engineering Laboratory for the purpose of shortening the elapsed time between missile development and its effective tactical use. This activity, established over 2 years ago, has proven that the quasi-simultaneous development and production of missiles can become a feasible reality.

The Tucson Engineering Laboratory is now expanding its scope of operations. Mechanical Engineers, Electrical Engineers, or Physicists who like to work on urgent problems and who have the ability and enthusiasm to constantly improve the product and its reliability, will find this an ideal environment. Specific areas of interest include: missile system analysis, infrared and radar guidance systems, electromechanical and hydraulic control systems, missile and test equipment and electronic circuit design.

An added advantage: Tucson's dry healthful climate. Investigate by sending resume to Mr. W. A. Barnes at:

the West's leader in advanced electronics

HUGHES

TUCSON ENGINEERING LABORATORIES

Hughes Aircraft Company

Tucson, Arizona

CIRCLE 15 ON INQUIRY CARD

DIRECT READING MASS FLOWMETER

Thermopile Circuit Compensates for Temperature

A flowmeter that uses a heated thermopile element in a flow tube provides direct reading of total mass flow of air or other gases, independent of temperature and pressure variations. The thermopile circuit is self-compensating for both ambient temperature and rate of change of temperature. The flow tube can be installed directly in the flow line or, large lines can be placed in a bypass to measure a fraction of the total flow.

The new instrument, developed by Hastings-Raydist, Inc. of Hampton, Virginia, is calibrated directly in milligrams of air per minute and is available in several flow ranges. It is especially well suited for measuring low rates of flow such as in gas chromatography.

This type of thermal flowmeter has several distinct advantages over the type that uses temperature rise across the heater as a measure of flow. Power requirements of the new meter are much less since the entire mass of gas flowing does not have to be raised in temperature. The unit causes a minimum of pressure drop in the line.

Many industrial and analytical processes require knowledge of total mass of gas flow. With instruments that use pitotstatic tubes or orifice plates indications of flow are proportional to density of gas and square of velocity at which it is flowing. In such cases necessary corrections for temperature and pressure changes are difficult and complicated in obtaining accurate measurements of true mass flow. With the Hastings Mass Flowmeters, mass flow is read directly.

Model MF-1 flowmeter has a range from 0 to 10,000 milligrams of air per minute, but offers highest accuracy and maximum readability for air flows in the range from 50 to 1,000 milligrams per minute. Model SM-1 has a range from 0 to 500 milligrams of air per minute. Models are available with a five-position selector switch which allows the monitoring of flow at several locations with the same indicating instrument.

Hastings flowmeters are suitable for use with control and alarm devices and self-balancing type recording potentiometers.

Circle No. 217 on Inquiry Card

Low-Capacitance Precision Pot

Precision potentiometer has low element to ground and element to element capacitance because the slip ring and resistance winding are isolated with phenolics where metal has been normally used. The inter-element capacitance and capacitance to ground are approximately 11 uufd with low inductance. Available in linear and 3 to 1 taper with resistances to 100,000 ohms, the pot may be ganged up to five units. Precision Line Inc., Maynard, Mass.

Circle No. 189 on Inquiry Card

WORTH FILING

Thermocouple Assemblies

12-page catalog describes each component comprising complete heavy duty industrial thermocouple assemblies and enables the user to create his own assembly part number. Six basic types of standard wire-type and "Ceramo" thermocouples in all standard gages and calibrations and six different thermocouple connection heads, including heavy-duty cast iron heads, aluminum heads with steel covers quick-opening aluminum heads, and 7-ounce aluminum heads are described and illustrated. Complete variety of connection fittings, built-up and bar stock thermowells, and protection tubes in eight different types are described in detail.

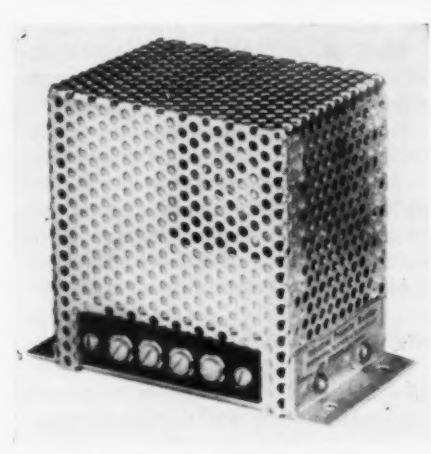
Source: Thermo Electric Co., Inc., Saddle Brook, New Jersey

For your copy: Circle No. 225 on Inquiry Card

Transistorized Power Supply

Compact, lightweight d-c to d-c transistorized power supply permits reliable operation at CCS rating under severe operating conditions through the use of a high-power PNP transistor switching circuit employing an ITT special pulse transformer. Using silicon diode rectifiers, the moderate switching rate used results in minimum noise interference.

Having a d-c input of 12.6 volts (±20 percent) at 1.60 amps nominal, 20 watts, and a d-c output of 210 volts at 87 mills nominal, 20 watts; the unit has 6 percent regulation, 90 percent efficiency and a ripple of less than 0.5%. Incased in a welded, cadmium plated, formed steel housing with gray lacquer overlay, weighing 1 lb 3 oz, and measuring 2½ in wide by 3 5/16 inches long by 3 7/16 inches high, the unit operates thru a temperature range of minus 55°C to plus 75°C,



and can be used as a replacement for dynamotor and/or vibrator power supplies of mobile receivers and other low power devices. Industrial Products Division, International Telephone and Telegraph Corp., San Fernando, California.

Circle No. 190 on Inquiry Card

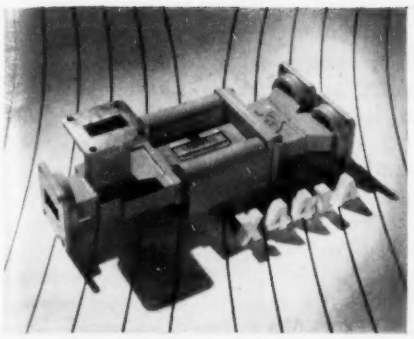
WORTH FILING

Condensed Oil Seal Catalog

68-page, fully-illustrated Condensed Oil Seal Catalog lists all C/R oil seals and has preface section which describes and illustrates the various C/R sealing member materials including Sirvis leather, Sirvis-Conpor leather and a wide range of Sirvene synthetic rubber compounds. A chart indicates the compatibility of each material with a wide range of media to be sealed. The catalog also has a complete section on engineering data covering the subjects of shaft materials, finish, hardness, shaft size and tolerance, shaft speeds, eccentricity, pressure, and lubrication. Complete installation procedure and diagrams are given in conjunction with this section.

Source: Chicago Rawhide Manufacturing Co. Chicago 22, Illinois

For your copy: Circle No. 218 on Inquiry Card



Ferrite Circulator

Ferrite Circulator covering the frequency band 8.5 to 9.6 kmc, transmits input power from one of the four waveguide terminals to the next in sequence. Giving forward insertion loss of 0.5 db, the unit exhibits a vswr of 1.20 with all arms terminated and is capable of 250 kw peak transmitted power with 250 watts average transmitted power. Operating temperature range is −55°C to +125°C and length overall is 8.4 inches. The unit can replace a conventional duplexer in a radar system and can isolate the transmitter from the receiver t-r tube by at least 20 db and in most cases by 25 db, with antenna reflections only, directed to the t-r tube. For this application, the anti t-r tube is eliminated completely. Cascade Research, Los Gatos, California.

Circle No. 200 on Inquiry Card

WORTH FILING

Thermistor Catalog

16-page brochure describes fifteen different thermistor circuits and gives specifications for nearly 400 different thermistors including assemblies, matched pairs, beads, discs, washers, rods, and probes. Section entitled "What Do Thermistors Do?" shows how various thermistor data can be used for circuit design.

Source: Fenwal Electronics Inc., Framingham, Massachusetts

For your copy: Circle No. 221 on Inquiry Card

WORTH FILING

Particle Accelerators

12-page booklet describes the many known and potential applications of both Van de Graaff and linear accelerators, utilizing photographs and line drawings to point up significant design and performance features. Condensed specifications provided in a table enable the reader to quickly determine the appropriate accelerator model for a specific program.

Source: High Voltage Engineering Corp. Burlington, Mass.

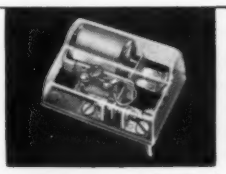
For your copy: Circle No. 60 on Inquiry Card

LOOKING FOR THE

SENSITIVE TYPE?

TRY THIS NUMBER SV-1C/5000D

The Advance type SV Sensitive Relay (shown at right) is 1⅞" high x 2⅞" long x 2⅛" wide. Also available is the type SO Miniature Sensitive Type, 1⅞" high x 1¼" long x 1⅛" wide.



SPECIFICATIONS

Coil resistance: From .005 Ohms at .005 volts DC to 40,000 Ohms at 14.0 volts DC.

Nominal power required: Factory adjusted at .005 watts.

Contact rating: 1 amp resistive, .5 amps inductive at 115 volts AC or 26.5 volts DC.

Contact arrangement: SPDT only.

Advance type SV relays are ultra-sensitive, yet durable—dust-tight, yet fully adjustable. Contacts and all working parts are protected by a transparent molded plastic cover.

Sensitivity can be adjusted from the 5-milliwatt factory setting by turning the vernier screws. Use the type SV in any DC circuit where power consumption is limited to a few thousandths of a watt.

Available from leading distributors

WRITE FOR COMPLETE DETAILS

Data sheets on the SV Sensitive Relay and the SO Miniature Sensitive Relay will be sent promptly.

ADVANCE RELAYS

ELGIN A PRODUCT OF ELECTRONICS DIVISION ELGIN NATIONAL WATCH COMPANY

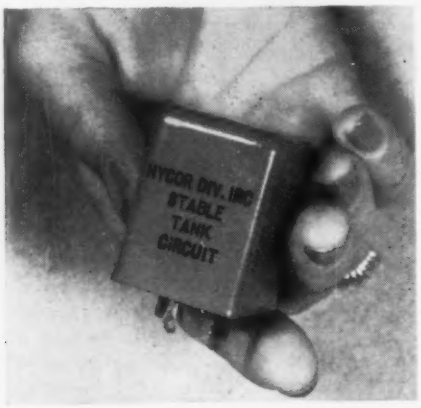
Dept. E, 2435 N. Naomi St., Burbank, California

FOR MORE INFORMATION CIRCLE 23 ON INQUIRY CARD

COMPONENTS DESIGN

Crystal Substitute

Stable Tank Circuits have been developed as a low cost substitute for crystals where high resistance to shock and vibration is needed, and ready adjustability over a considerable frequency range is desired. Potted in silicone rubber and hermetically sealed, these units are particularly well suited to applications in which the full stability of a crystal is not required but mechanical strength and low cost are of prime importance. Typical applications include use in oscillator tank circuits, discriminators, filters and frequency meters. The stability characteristics are more than adequate for most applications. Special temperature compensation and adjustability characteristics of



the units permit them to meet specifications like the following: Resonant frequency—20 kc; Temperature Range—10°C to 85°C; Allowable Frequency Shift: ±.1%; Specified Frequency at 25°C: ±.01%. Hycor Div., International Resistance Co., Sylmar, Cal.

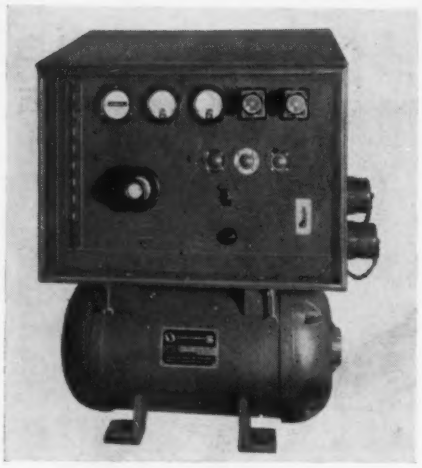
Circle No. 182 on Inquiry Card

WORTH FILING

Pilot Light Digest

2-color 16 page digest contains full page illustrations and technical information disclosing required voltages, mounting provisions and hardware, insulation, lens holders and colors, terminal types, finishes, and circuit diagrams for many categories of pilot lights, including sub-miniature indicator lights, pilot lights with built-in resistors for neon lamps, enclosed-type assemblies for incandescent and neon lamps, edge lighting assemblies, light shields, dimmers, oil-tight indicator lights, press-to-test and press-to-switch indicator assemblies.

Source: Dialight Corporation
Brooklyn 37, N. Y.
For your copy: Circle No. 168 on Inquiry Card



400-Cycle Motor Alternator Set

A 400-cycle motor alternator set has been developed which has no commutators, slip rings or rotor windings. Designed to supply power for high-frequency machine tools, flight simulators, computers, aircraft ground support equipment and other applications requiring 400-cycle power, output voltage is very closely maintained by control equipment integrally mounted on the motor-alternator set. Having low radio noise level and low harmonic content, the units are available in ratings from 1.5 to 10 KW with 80% power factor and operate from a 3 phase, 60 cycle, 120/208 volt source. Output is single phase 115 volts 400-cycles. Star-Kimble division of Safety Industries Inc., New Haven, Conn.

Circle No. 188 on Inquiry Card

Low-Torque Precision Pot

Designed for military fuel gage systems, a miniaturized low-torque high-speed precision potentiometer is suited for applications requiring better than average accuracy and response. Torque is 0.2 oz-in; independent linearity is 0.5 percent. Closer linearity tolerance is available on special order. The unit has an anodized aluminum housing, a stainless steel shaft and servo type mounting. Case diameter is ⅝ inch and case length is 21/32 inch. Available in the following standard resistance 1K, 2K, 5K and 10K, and up to 100K ohms on custom jobs. Precision Line Inc., Maynard, Mass.

Circle No. 54 on Inquiry Card

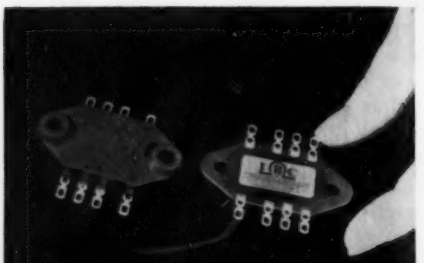
Milli-Microsecond Switching

Switching time of 0.9 milli-microsec, believed to be the world's fastest, is now possible with a new germanium diode. Intended for critical computer applications at normal transistor bias levels, these diodes simplify circuitry and reduce the number of required transistors. Transitron Electronic Corp., Wakefield, Mass.

Circle No. 55 on Inquiry Card

Precision Decade Resistor Blocks

Four precision resistors have been potted in one specially designed block to form a precision decade resistor that can mount on the tie rods of standard wafer switches. The decades can be mounted with short leads in the chassis of the equipment being tested and can be adjusted while in position. This permits the engineer to change the value of the resistance as needed, without stray capacitance and pickup associated with conventional decade boxes and leads. Any combination of the four resistors may be hooked into the circuit under test to obtain resistance values from one to



ten ohms. This decade is particularly adaptable to experimental units or small manufactured lots and are economical enough to remain as a permanent part of the test equipment. Hycor Division of International Resistance Co., Sylmar, California.

Circle No. 181 on Inquiry Card

WORTH FILING

Cannon Plugs

16-page catalog describes Cannon series CT connectors, a lighter, shorter version of the MS-E environmental-resistant connectors. A second 8-page bulletin describes the new EX Cannon connector line for use in high-altitude, high vibration applications and shows the many variations in shell size and insert arrangements available.

Source: Cannon Electric Company
Los Angeles 54, California
For your copy: Circle No. 145 on Inquiry Card

WORTH FILING

Automatic Transfer Switches

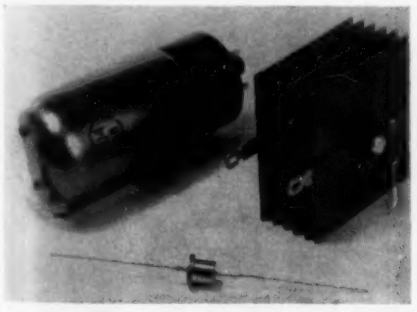
How to select an automatic transfer switch and applications of this equipment is subject of 24-page booklet. It discusses such requirements as inrush capacity, continuous duty rating, rapid transferral of load, high thermal capacity and ability to withstand electromagnetic effects.

Source: Automatic Switch Co.
Florham Park, New Jersey
For your copy: Circle No. 134 on Inquiry Card

Variable Transformer

Dust-tight variable transformer with easy access to the interior can be installed or removed from its enclosure without disturbing the mounting section or conduit connections and can be mounted in a variety of positions. Single units and ganged assemblies deliver a continuously-adjustable voltage from 120, 240 or 480 volt, single and three phase power lines. Ratings are from 2.6 to 8.5 amperes constant-current load with up to 12.5 amperes constant-impedance load. Superior Electric Co., Bristol, Conn.

Circle No. 91 on Inquiry Card



Low Cost Miniature Power Rectifiers

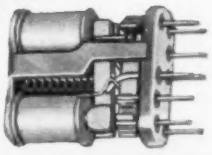
Mass produced miniature silicon power rectifier (foreground) available in large-scale quantities for applications in commercial-consumer products will sell for as low as 40 cents to $1.50 each in quantity, depending on the peak voltage required for the application. Rated at 500 milliamperes average rectified current at 100°C, the eight types in the series cover a range of 50 to 500 volts. They are designed with convenient pigtail leads for easy mounting in any position. General Instrument Corporation, Automatic Manufacturing Div., Newark 4, N.J.

Circle No. 61 on Inquiry Card

EVERYTHING UNDER CONTROL

GUARDIAN® *Leadership*

in electromagnetic control began more than twenty-six years ago when Guardian became dedicated to the control of maximum power in minimum space. Here you see preferred standards of micro-miniature, sub-miniature and miniature control of today's aircraft, missiles and electrical industries.



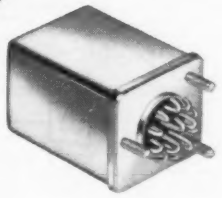
Series 1005 Relay
Micro-Miniature Control
L. 27/32" W. 25/32" D. 11/32" (maximum)

3 Amp Double Pole, Double Throw. Meets or surpasses requirements for all specifications of MIL-R-25018 and MIL-R-5757C. No exceptions. Contact Rating: 3 Amps at 125° C. per MIL-R-25018; 2 Amps at 125° C. per MIL-R-25018 and MIL-R-5757C Hermetically sealed. Specify plug-in or solder hooks.

$5.90 each in lots of one thousand f.o.b. Chicago, Ill.

Series 2005 Relay
Sub-Miniature Control
L. 2¼" W. 1 7/32" D. 1 7/32" (maximum)

5 Amp 6 Pole, Double Throw. Meets or exceeds MIL-R-6106B and MIL-R-5757C. Built to withstand 100 G shock. Vibration resistance is 10 G minimum from 75 to 2000 c.p.s. in all mounting planes. All contacts rated at 5 Amps 24 to 30 v. D.C., resistive load. Operates with voltage variations as low as 16 v. at 25° C., ambient.



Series 3205 Relay
Miniature Control
L. 2½" W. 1 31/32" D. 1 7/16" (maximum)

10 Amp 4 Pole, Double Throw aircraft and missile relay uses same size envelope as AN 3304 (4 P.D.T. 3 Amp relay) and is approximately the same weight. Designed to meet and exceed test requirements of MIL-R-6106B, Class B. Meets minimum current requirements of military specifications.

Write for circulars giving complete specifications

GUARDIAN ELECTRIC
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1641-H W. WALNUT STREET, *"Everything Under Control"* CHICAGO 12, ILLINOIS

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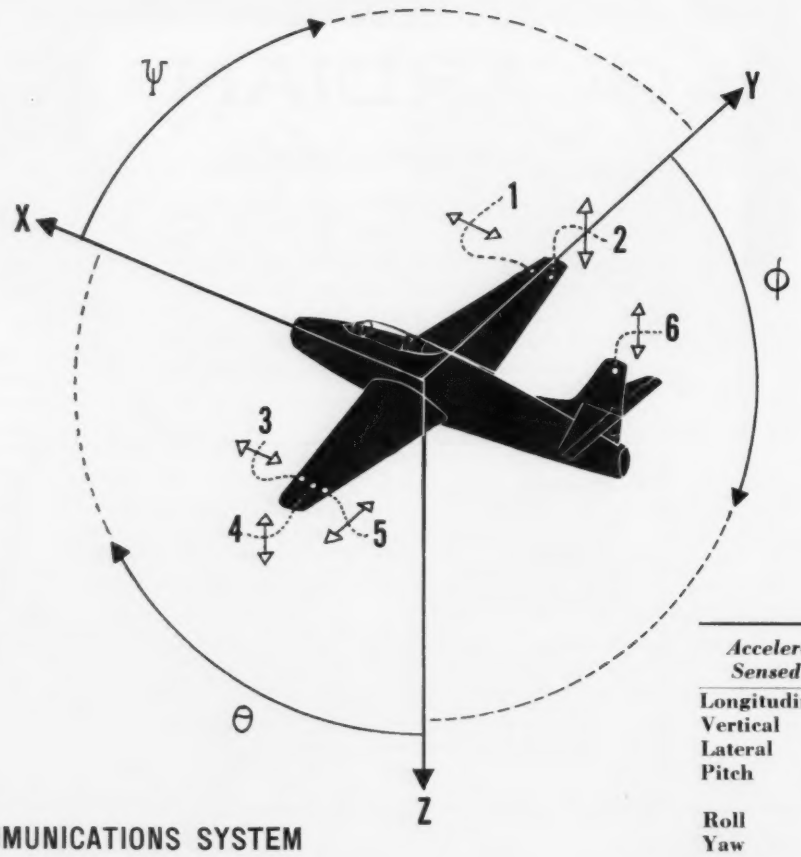

Fig. 1—Mounting position of the six accelerometers on the airplane. The axes of the accelerometers are defined to measure accelerations in the directions shown. The output of the accelerometers define completely the acceleration pattern of the aircraft. For example: Equal outputs from units 1 and 3 define horizontal acceleration. Any difference between the outputs of units 1 and 3 would define a yawing acceleration. The acceleration components can then be classified as follows:

Acceleration Sensed	*Positive Val.*	*Negative Val.*
Longitudinal	+1 = +3	−1 = −3
Vertical	+2 = +4 = +6	−2 = −4 = −6
Lateral	+5	−5
Pitch	+2 = +4 and +2 or +4 −6	−2 = −4 and −4 or −2 +6
Roll	+4 −2	+2 −4
Yaw	+3 −1	+1 −3

COMMUNICATIONS SYSTEM

Tactually Communicated Data Speeds Human Control of Aircraft

Vibratory stimuli can overcome some communication problems caused by human reaction-time delay and visual and aural sense saturation. Addition of touch to the senses of personnel involved in communication-action chains helps them consciously separate incoming sense data so they may quickly and accurately respond in a predetermined manner to emergency or control situations.

These are observations of Joseph Hirsch, consulting engineer, Pacific Palisades, Cal., who has successfully developed tactile communication systems for education of deaf and blind people. This method of communication uses a coding of vibro-tactile stimuli based on interchangeable permutations and combinations of different frequency vibrations on the several fingers.

Stated generally, this development permits intelligence in the form of numbers, letters, basic English, automatic control data or other bits of information to be transmitted to a receiving station. At the station, the intelligence is converted into a vibration that can be sensed and interpreted by the receiver. Mr. Hirsch prefers a sys-

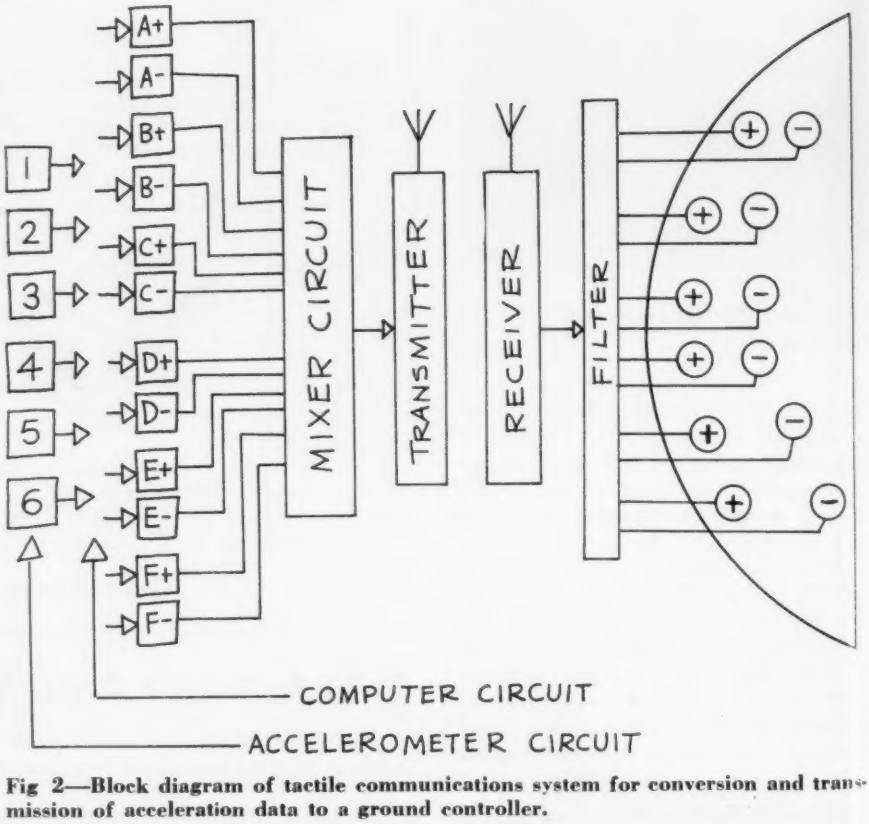

Fig 2—Block diagram of tactile communications system for conversion and transmission of acceleration data to a ground controller.

CAPACITY FOR ACHIEVEMENT

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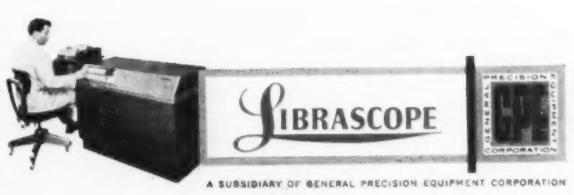

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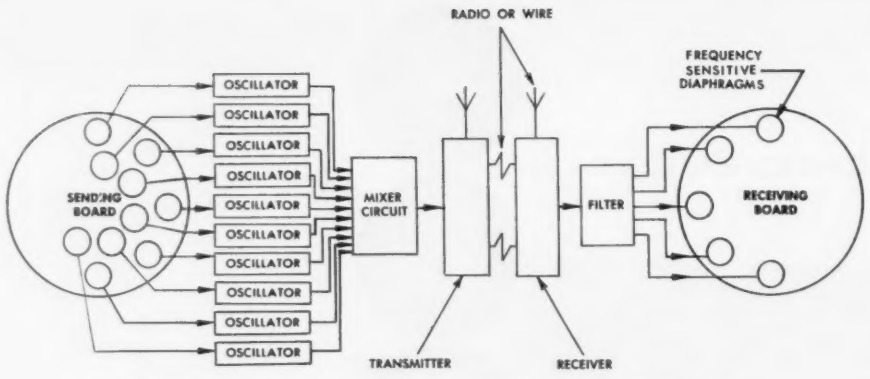


Figure 4—Apparatus for communicating—sense of touch.

that can be sensed and interpreted by the receiver. Mr. Hirsch prefers a system design that uses a number of transmitting and receiving channels; if each sending channel (Fig. 4) transmits a particular frequency and each receiving channel accepts two particular frequencies, the permutations and combinations of transmitted frequencies add up to a total of 637 symbols at the receiver.

This system could be extended to one in which three separate frequencies transmitted to each finger represents 4,945 symbols or words. Multiple frequencies are also possible by using single jack plugs; pressing the sending button to a preset depth controls the frequency level.

More recently, he has developed two aircraft ground control tactile communications systems, and a tactile aircraft collision anticipator system.

BACKGROUND

According to Mr. Hirsch, command signals which must be sent from lookout personnel on military ships to central control or gunnery stations frequently cannot be transmitted by audio intercommunications methods quickly enough to be effective. Human reaction time delay prevents a ground controller from acting immediately on some signals transmitted automatically by the usual communications devices on military aircraft. Many pilots and tank drivers, he says, cannot respond to warning horns and other aural signaling devices because their hearing is saturated by noise levels approaching the threshold of pain. The human voice transmitted by radio telephone is also subject to certain deficiencies, such as slowness and signal distortion.

Visual presentation of data to a pilot is not much better, Mr. Hirsch says, because the pilot's visual sense channel is already saturated in the process of flying the aircraft. During landings and takeoffs, he must focus on nearby intruments and instantaneously refocus on a distant runway. If he is required to make a response, the time required for visual accommodation and convergence, as he changes focus, must be added to his reaction time. Although auditory stimuli have better attention demanding characteristics than visual stimuli, says Mr. Hirsch, vibratory stimuli trigger the nervous system faster and therefore provide a finer degree of control in systems where the human link cannot be dispensed with.

TACTILE COMMUNICATIONS SYSTEMS

Mr. Hirsch suggests three applications of tactile communications to aircraft control. First, if the attitude of the airplane as defined by its yaw, pitch, and roll could be transmitted to a ground controller by automatic devices on the aircraft in such a manner that he could receive this data in the form of vibratory stimuli, a quicker and more accurate control of the airplane could be accomplished.

Since attitude positions are a result of relative accelerations of different parts of the airplane, Mr. Hirsch has developed a ground control system using six accelerometers mounted in strategic parts of the airplane (Fig. 1). Each accelerometer puts out a signal with unique polarity and magnitude. The ground control operator identifies a particular acceleration component by feeling oscillating diaphragms under his fingers. Two diaphrams are used for each finger, one under the tip for positive values of acceleration components and one under the middle part of the finger for negative values of acceleration components. The frequency of vibration of the diaphragm is a function of the magnitude of the acceleration component.

The signals are relayed from the airplane to the ground by the usual methods of radiotelemetry (Fig. 2). When the ground control operator gets used to the feel of the system, he can literally fly the plane by the "seat of his fingers."

In addition, the tactual communication link could be used separately or in conjunction with other intelligence receiving and communication sources. The ground control operator could for instance correlate this acceleration data with other data at his command and achieve a safer landing.

Mr. Hirsch says that finer control can be achieved by the use of this proposed system since a future change in attitude or displacement results from a present acceleration. The ground control operator can then signal aurally or tactually any necessary corrections to the pilot in the airplane and if pilotless aircraft are used, the ground control operator can automatically control the aircraft in flight.

Mr. Hirsch is also considering a provision for dispensing tactually to the pilot or the ground control operator altitude and velocity information in addition to attitude information (Fig. 3). The tactual reception of such

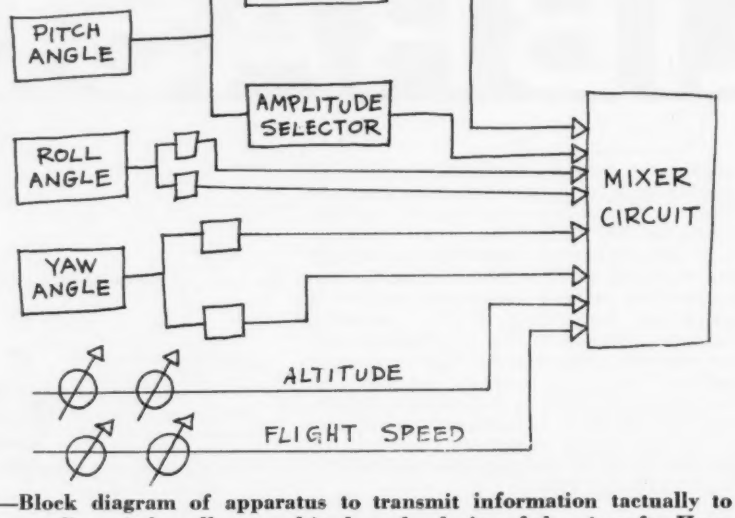
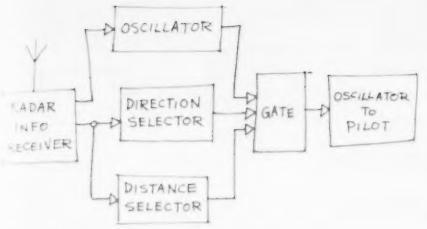


Fig 3—Block diagram of apparatus to transmit information tactually to a receiver regarding pitch, roll, yaw, altitude and velocity of the aircraft. Here again, frequency of the vibrated diaphragm is a function of the voltage output from the altitude and flight speed indicators.



Block diagram of collision anticipator.

information, he says, will be of two-fold importance to the pilot: (1) During takeoff, his other sense organs may already be over-saturated. (2) In emergency situations, faster pilot response is of utmost importance.

He points out that tactually received information is particularly valuable in emergency situations since a learned response to tactual information is faster and more attention demanding than aural or visual information.

Mr. Hirsch proposes that the tactual link be used in a third system as a collision anticipator (Fig. 4). If search radar indicates the aircraft is on a collision course, a tactual signal is sent to the pilot who changes course instantly. He is immediately aware of the correctness of his new course by tactual signals of increasing or decreasing frequency.

Circle No. 174 on Inquiry Card

WORTH FILING

Quick-disconnects

General catalog describes the five basic Snap-Tite quick-disconnect couplings including the "H" coupling for high pressure applications, the "IH" coupling for impact in air lines, the "Hi-Flow" coupling for low pressure applications, the "E" coupling for vacuum and very low pressures, and the "T" coupling for hard to handle fluids. Construction details of all couplings are illustrated by generous use of cutaway drawings. Spare parts and dimensions and accessories are pictured and described. Graphs and tables show flow and pressure drop data for the "H" and "IH" couplings.

Source: Snap-Tite Inc.
Union City, Pa.

For your copy: Circle No. 219 on Inquiry Card

WORTH FILING

Transformer-Rectifiers

Four 2-page bulletins describe 1 amp, 25 amp, 100 amp, and 200 amp unregulated transformer-rectifier airborne power supplies. Photos, graphs, line drawings, and lists of electrical and mechanical characteristics illustrate these 4 units.

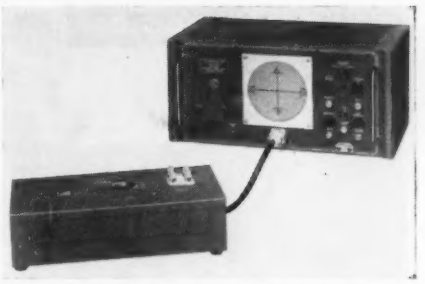
Source: General Electric Co.
Schenectady 5, New York

For your copies: Circle No. 229 on Inquiry Card

Q Comparator

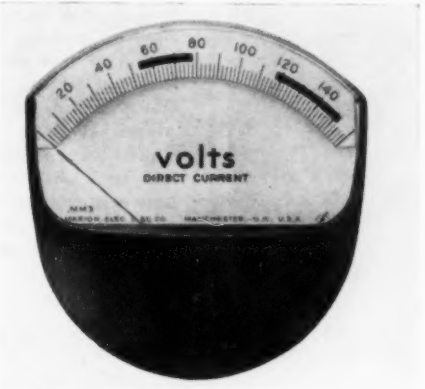
Q comparator instantly production tests coils, capacitors, and resistors with an ease and accuracy previously unavailable. The unit is comprised essentially of a swept-frequency oscillator, Q meter-type measuring circuit with detector, vertical amplifier, differentiator, spot generator, horizontal amplifier with blanking circuit, cathode-ray tube, and power supply. The swept-frequency oscillator and measuring circuit are assembled into a relatively small unit which is cable-and-plug connected to the main unit containing the cathode-ray tube and remaining circuitry.

A test engineer or other suitably skilled person sets up the comparator using a standard component having the characteristics desired in the production components. A dot forms at the center of the CRT when the standard component is connected to the Q comparator's test circuit. Comparatively unskilled personnel can then check production components rapidly by connecting them to the test circuit and observing the position of the dot on



the CRT. If the dot does not appear at the center of the CRT, the component under test is different from the standard. Deviation along the vertical axis shows a change in Q, and deviation along the horizontal axis shows a change in L (inductance) or C (capacitance). Limit conditions can be grease-penciled on the CRT enabling the operator to note easily any dot falling outside these rejection boundries. In addition to performing this go-no-go function, the instrument supplies trend information quickly, so that in many cases production can be altered before rejects occur. Boonton Radio Corporation, Boonton, New Jersey.

Circle No. 191 on Inquiry Card



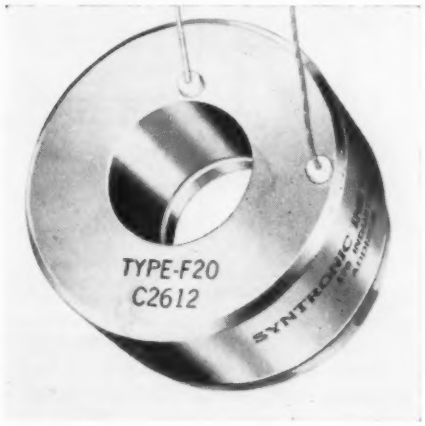
Anti-parallax Meter

New panel meter has anti-parallax scale with dial markings in the same plane as the pointer. The calibrated portion of the scale is raised from the dial face to coincide with the plane of the pointer allowing quick, accurate readings to be taken from a distance or at an angle. The pointer tip swings under the scale so that calibration marks, from any angle, appear to be a continuation of the pointer, eliminating errors due to parallax. In addition, the meter incorporates all features of standard Medalist meters including scale length 40% greater than that of regular 3½ inch meters, and plexiglas fronts available in a wide variety of colors. Custom dials with customer's names, trademarks, etc. are available on special order. Marion Electrical Instrument Co., Manchester, N. H.

Circle No. 197 on Inquiry Card

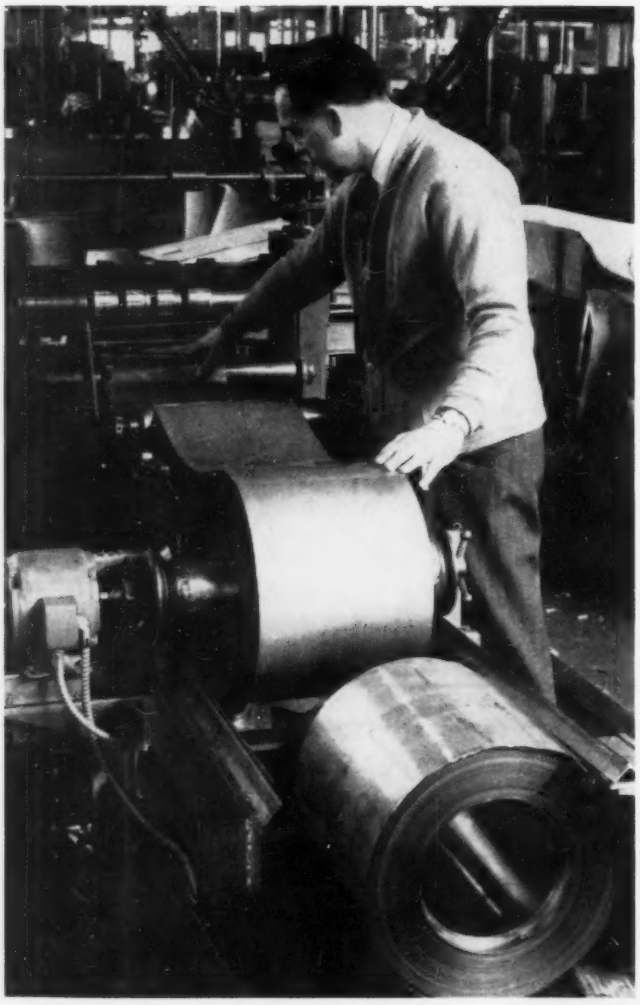
Hi-Power Focus Coil

Electromagnetic focus coil has been designed for photographic, flying spot, military and other special purpose cathode-ray tubes (1½ inch neck diameter) requiring short focal lengths at high (up to 25KV) accelerating potentials. Minimum spot distortion is assured by machining the coil case to close dimensional tolerances. A uniform focusing field is assured by using top quality soft magnetic iron in the case



and sharp focus for high beam currents is assured by the large I.D. to focus gap ratio. Available in a wide range of coil resistances, the coil measures 1 9/16 inches I.D., 3½ inches O.D., 1⅞ inches long and 5/16 inch front to gap center. Syntronic Instruments, Inc., Addison, Illinois.

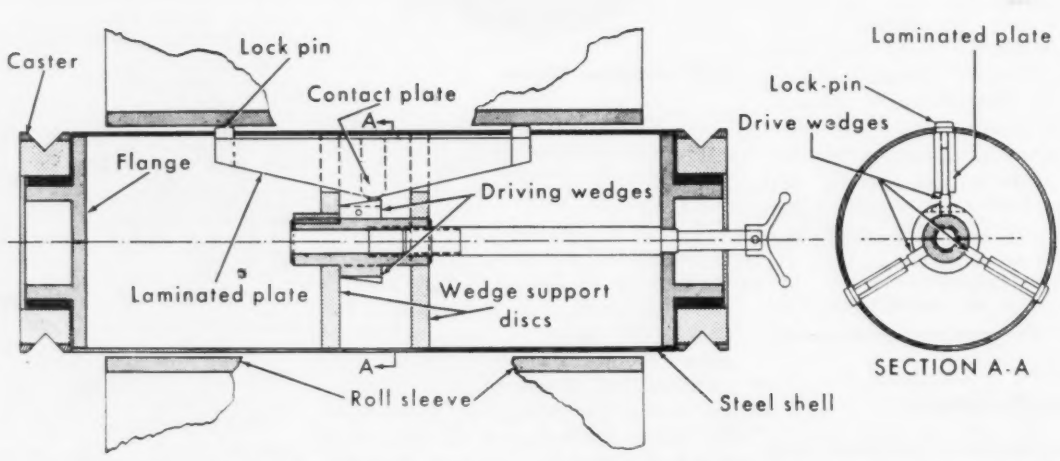
Circle No. 195 on Inquiry Card



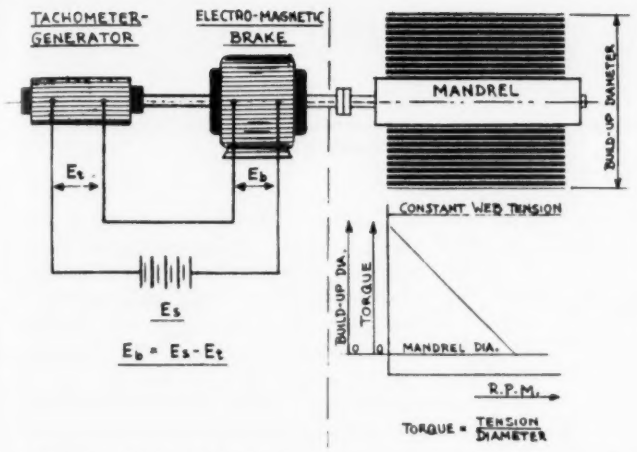
A Rolled Material Handling System

Electromechanical design techniques have recently been applied to problems of handling rolled materials such as paper, textiles, sheet metals, etc. The modules described and illustrated here comprise a system, tradenamed Rollmat by MFI (Machinery for Industry), which makes use of electromechanical constant-tension and constant-speed controls to solve problems of loading rolled materials into production machinery, unwinding them for feeding, and winding up material after processing. The units, which may be used in combination or separately in many applications, are an expanding mandrel for holding the roll, a loading ramp for handling the roll, three windup units and an unwinding or constant-tension device.

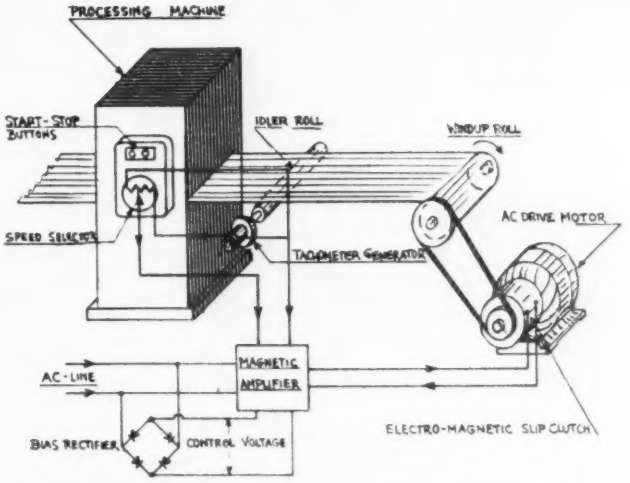
A Loading Ramp **and platform permit use of the mandrel in a simplified loading technique. A power truck or overhead conveyor places the rolled material on the loading platform. The mandrel is inserted and locked, and the reel is rolled over the edge of the platform on to the loading ramp. This ramp consists of an inclined plane and two less sloping rails. As the reel moves down the inclined plane, the rails pick up the V-grooved wheel of the mandrel, and cause the reel to lift clear of the inclined plane. It then rolls down the rails to the stops at the unwinding position. Rails and stops assure alignment of the reel with the processing machine. Slope difference between the rails and inclined plane make it possible to accommodate rolls of varying diameter; rolls of larger diameters are picked up by the rails at points closer to the stops.**



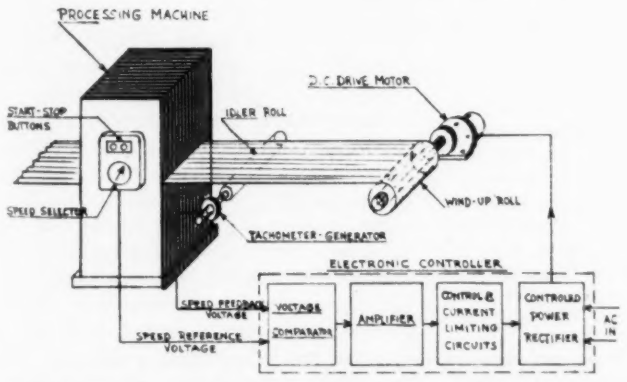
The Expanding Mandrel **is designed to be quickly and easily inserted into the core of the rolled material. One or two turns of a handwheel causes three sets of locking pins to expand and engage the core. These locking pins are self-aligning to equalize internal pressure on the core and assure uniform gripping. If the core material is soft, locking bars replace the locking pins and distribute gripping pressure over larger areas to prevent wear and distortion. Two V-grooved wheels, one at each end of the mandrel, rotate with respect to the mandrel and transport the rolled material to the unwinding position, where they become stationary bearings on which the mandrel rotates. The mandrel is light. Most sizes can be handled by one man and yet support rolls weighing many thousands of pounds. A typical mandrel weighing 25 pounds can support a 2000-pound roll turning at 600 rpm.**



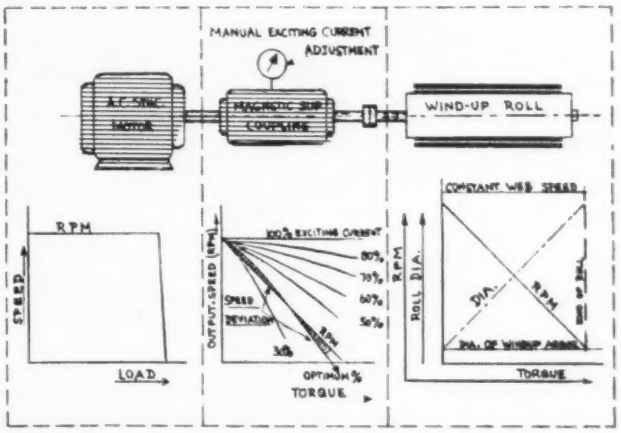
A Tension Unit **aligned with the stopped mandrel controls the tension of the rolled material as it is fed into the processing machine. This tension unit permits application of either constant-torque or constant-tension to the material and consists of a rotating electromagnetic brake and associated controls. When the roll and mandrel are in position, power is applied to a solenoid which couples the brake to the mandrel. Constant torque is achieved by supplying constant control current to the brake. This torque can be adjusted over wide ranges. Constant tension is maintained by a tachometer generator and current regulator. The tachometer generator is coupled to the brake shaft and is driven by the mandrel. Output of the tachometer generator is proportional to rotational speed of the mandrel, and inversely proportional to the radius of the rolled material. As the material unwinds, its radius decreases, its rotational speed increases, and output of the tachometer-generator increases. This output is fed to the current regulator which controls exciting current of the brake to maintain constant tension.**



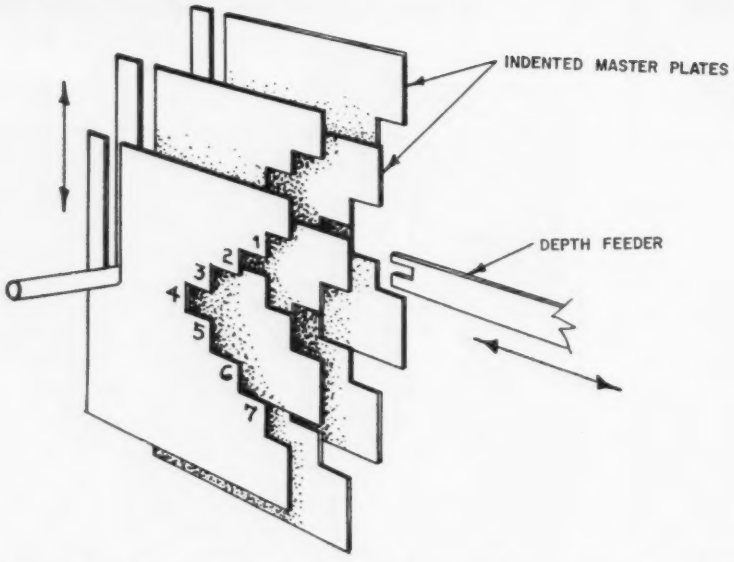
Type-1 Windup Unit **includes an ac drive motor, an electromagnetic slip clutch, a tachometer-generator, and a magnetic amplifier current regulator. The windup unit rolls up the processed material at constant speed or at constant speed and tension. The drive motor couples to the windup shaft through the variable coupling. Sheet material passes over an idler roll which drives the tachometer-generator. Output of the tach-gen, which is proportional to the linear speed of the sheet, is fed to the magnetic amplifier together with the bias control voltage. Differential voltage produced is amplified and controls the current that excites the stator windings of the electro-magnetic slip clutch to control its speed and torque. If the sheet does not move at the desired speed the differential voltage varies accordingly and produces the corrective current to make the clutch slip at the proper rate.**



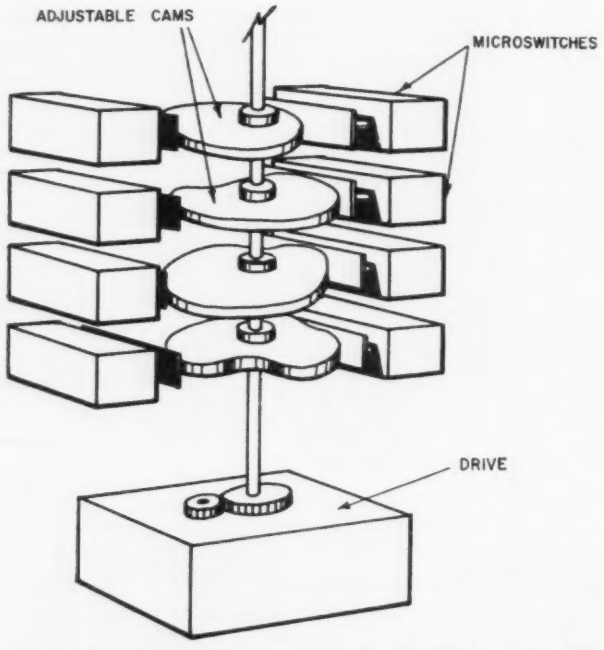
Type-2 Windup Unit **includes a dc drive motor, a tachometer-generator, an electronic controller, and an operator's control station. Again the sheet passes over an idler wheel which drives the tach-gen. Voltage output of the tach-gen is proportional to linear speed of the sheet. The operator selects desired speed by setting the calibrated speed selector, which generates a corresponding speed reference voltage. This speed reference voltage and the tach speed feed back voltage are fed to a voltage comparator. The difference between the two voltages produces an error signal that is amplified and fed into the control circuitry which varies the d-c output of the controlled power rectifier. The resultant current controls speed of the drive motor. This system also can be used for stopping the windup roll when a desired build-up diameter has been reached. A circuit breaker disconnects the motor armature from the power supply and reconnects it as a generator across a bank of load resistors to supply dynamic braking.**



Type-3 Windup Unit, **a constant-tension payoff device, is comparatively inexpensive open-loop control for use where speed can be allowed to vary slightly. A magnetic slip coupling of proper characteristics mounts on a constant speed motor and the output shaft of the coupling connects to the windup shaft. As the diameter of the rolled material increases, torque increases proportionally. If exciting current of the coupling is held at a constant value, slip will increase in proportion to load. Thus combination of these two factors—linear increase in torque load and almost linear slippage with load—gives nearly constant speed of the processed material. No controls are necessary for this operation. Because of the nature of its components, the system is self balancing. For optimum constant speed performance, exciting current of the coupling can be manually manipulated. Performance characteristics of each of the elements of this windup drive are shown.**



Arrangement of plates. Indented plate device contains a series of indentations to store memory data and translate a specific pattern for multi-operational use as found in computers.



Mechanical timer. Cams arranged in banked or grouped assemblies can impart intelligence as input, can select or can activate components to generate a function. Cams are used in engine cam-valve operation, timing devices and program and sequence mechanisms. "Memory" of the system may be altered by rearrangement of the angular position of the respective cam units. In those applications requiring less than 200 cycles per minute, standard cam practices may be used. However, technical advances, which have been made in the electronic field in recent years make it possible for memory units to perform a high-speed function. Some of the general criteria in selecting this type includes consideration of the required performance specifications in terms of frequency of operation, number of memory elements or cells in the system, space requirements, angular rotational velocity of the cam-and-follower system and the general characteristics of the generated cam profile. A further extension of the sequence-control class of the memory functions may be found in camshafts. This class of mechanisms performs a more involved task than that specified for ganged cam-sequence-control operation. Ganged cam arrangements act primarily as control functions, while camshafts may be used for actual mechanism movement; for example, engine-cylinder valving. This class of mechanism can be brought into the category of mechanical memory by application of the ground rules which call for intelligence input and for the selective functions, in time, as output. Memory may be altered by changing cam-lobe positions angularly.

MEMORY DEVICES

Six Multi-element Electromechanical and Electrohydraulic Memory Devices

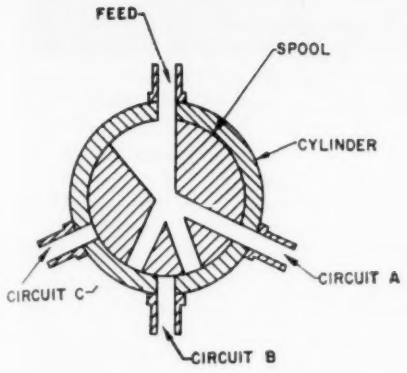
The criteria in selecting mechanical devices must satisfy three basic elements. The first is the input or sensing intelligence. The second is selectivity or the selection of a particular element in time. The third is the mechanical translation or the actual mechanical memory function. So stated Arthur Mirel at the Design Engineering Conference held last April in Chicago by the American Society of Mechanical Engineers.

Some examples of mechanical components having basic memory characteristics are banked cam assemblies, hydraulic barrel or sleeve valves, interlocks, key-and-tumbler-lock arrangements, memory wheels, limit switches, float controls and phonograph-record arrangements.

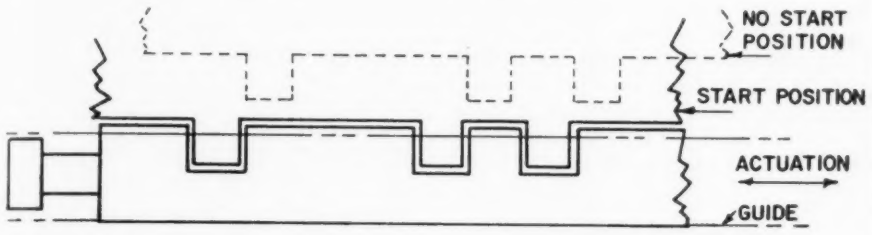
In the application of the infinite variety of memory component combinations, Mr. Mirel pointed out, you may find it necessary to rely upon your ingenuity in developing useful devices which fall outside the category of "standard" components. However, an examination of those devices termed "standard" versus those of ingenious design must begin with a listing of elementary memory devices, such as the cam, and then follow an evolutionary cycle through to the more complex multi-element electromechanical and electrohydraulic mechanical concepts.

One general distinction in making a comparison of mechanical-memory components to all-electronic systems is the capacity of the electronic systems to store a greater variety of intelligence with an instantaneous response for translatable information for the initiation of motion. However, this is not accomplished without the use of complex circuitry and involved component arrangement. Mr. Mirel made the point to establish the optimum area of application that exists for the selection of mechanical versus electronic systems. As part of this consideration, careful analysis of the limitations relating to the design problems of kinematics in high-velocity mechanisms, compatibility with the total assembly, fail-safe possibilities, response time, machinability, inspection and test must be made.

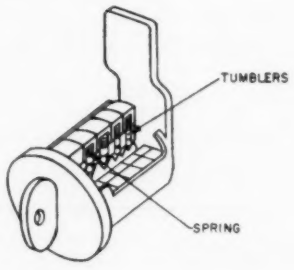
Arthur Mirel is Assistant Section Manager, General Engineering Laboratories, American Machine and Foundry Company, Greenwich, Connecticut.



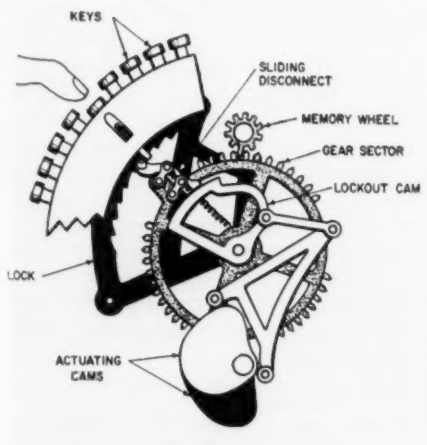
Hydraulic principles. To achieve sequence control of multiple functions in time, a rotating or sliding rotor moves to align with parts machined into an outer cylinder. This arrangement provides memory in the form of selected functions of multiple hydraulic circuitry in proper time relationship.



Notched bar. An interlock usually consists of a bar mounted for a sliding or pivoting motion with a series of stations represented by notched configurations and a switch to monitor correct position of the interlock for functional purposes. In operation, intelligence is imparted through the actuation of the bar, with the machine components, memorizing predetermined and correct conditions for proper starting as determined by the alignment of notches. Limiting factors insure that full actuation of the bar is accomplished to prevent the inertial effect of machine motion from being imparted to the bar. This results from conditions inherent in those classes of machinery incorporating flywheels or having high inertia start characteristics, as found in certain electrical drives and in hydraulic or pneumatic applications. One method commonly employed to correct this condition is to monitor the position of the bar with respect to proper start and to impart this information to the prime start power control source.



Lock and key. Tumbler-lock arrangements represent the next higher level in the order of complexity evolving from notched interlocks. The application of key notches in this case imparts intelligence in the form of sensing a predetermined memory pattern. When the proper arrangement of notches is selected, useful motion ensues; a lock is "locked" or "unlocked".



In totalizer memory units selected information related to a bank of numbers arranged in series is fed as input intelligence to a machine. This input is stored for readout at a later point in time, usually through the actuation of a totalizer bar. The readout is accomplished through a mechanical arrangement of memory wheels each of which has numbers from 0 to 9 on its periphery. The depression of any of many numbered keys determines the value of angular rotation of a sweep mechanism which controls a gear sector and a latch-cutout component. This determines correct angular rotation of the memory wheel when it engages the main-gear sector on the return stroke.

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RESEARCH

RUBIDIUM MAGNETOMETER

New Method of Measuring Magnetic Forces

Two Commerce Department scientists have perfected a method of measuring the magnetic forces that originate inside the earth and in outer space. The scientists are T. L. Skillman of the Survey's Fredericksburg (Va.) magnetic observatory and Dr. P. L. Bender of the National Bureau of Standards. Rear Admiral H. Arnold Karo, Director of the Coast and Geodetic Survey, Department of Commerce, predicts the development will provide scientists with magnetometers (instruments for measuring magnetism) far more precise and compact than those now available.

A beam of light is sent through a tube containing a small quantity of vaporized rubidium (one of the alkali metals). The manner in which the light is absorbed indicates the strength of the magnetic forces. The explanation is that the absorption of light depends on the spinning of the electrons in the rubidium molecule, and the spin in turn is controlled by the magnetic force or field.

"We consider this an important scientific advance," said Admiral Karo. "It gives the geophysicist a new tool. Instruments embodying the principle will be simple, highly miniaturized, and capable of measuring very small magnetic fields—perhaps one billionth of the magnetic force developed by the motor that runs an apartment house elevator. They will be suitable for use in rockets and satellites. One possible application is in planned probes of the moon.

"A question to which science wants an answer is whether the moon has a magnetic field. It is believed that if there is such a field, it is fantastically weak. The rubidium magnetometer will be capable of measuring forces not otherwise detectable. Better understanding of the megnetism in outer space will help science toward the solution of basic questions concerning the origin of the universe."

Mr. Skillman has charge of the magnetic research laboratory at the Fredericksburg Observatory. He and Dr. Bender who is a physicist in the atomic physics section at the National Bureau of Standards, have prepared an announcement of the development for the Journal of Geophysical Research. They have been collaborating on other work of common interest to their agencies, both of which are in the Department of Commerce.

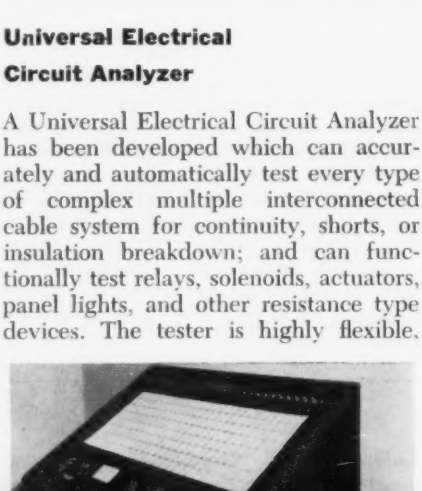
The rubidium magnetometer is expected to be of advantage in the laboratory and in geophysical prospecting for oil and metals.

Prior magnetometers have been of three types. The original form depended on the action of suspended magnets, and was unsuitable for use in any moving vehicle. During World War II an induction magnetometer was developed, but is regarded as unstable. The latest, called a proton precession magnetometer, has been used in some rockets and satellites, but like the others it fails in very weak magnetic fields.

Within recent months a number of physicists have suggested research in alkali metals looking toward better magnetometers, and several government and private agencies have conducted experiments with them.

Universal Electrical Circuit Analyzer

A Universal Electrical Circuit Analyzer has been developed which can accurately and automatically test every type of complex multiple interconnected cable system for continuity, shorts, or insulation breakdown; and can functionally test relays, solenoids, actuators, panel lights, and other resistance type devices. The tester is highly flexible,



because adaption to any particular cabling system or panel assembly requires only the use of an adapter cable. Its operational simplicity enables the average worker to learn its operation very quickly and perform tests in a matter of seconds—the tester will check circuits at the rate of ten per second.

Visible matrix type reference charts enable the operator to pin-point circuit errors. The analyzer has two test voltages—28 volts d-c and 500 volts d-c. An electronic detector approves or rejects circuits consistently to pre-set values, and an ohmmeter on the front panel allows the operator to conveniently measure the exact value of any circuit resistance, if desired. Push button switches permit the operator to manually select any test position at any time during a test cycle. Four Ampheol quick disconnect 100 contact receptacles provide convenient connection to the tester, and permit the operator to use the Analyzer for many jobs. For example, adapter cables for a particular test set-up can be in the process of being connected to their system while the analyzer is being used on another cable system. As soon as the test is completed, the tester can be quickly disconnected and changed over to the new job with another set of adapter cables. Costs of testing at any stage of production, modification, or maintenance are reduced, and engineering time devoted to special equipment for each test job can be released for other productive work. An auxiliary receptacle is provided for the operation, independently of the main test circuit, of external relays at any test position. The detector unit, power supply, relays, and other components are unpluggable and may be removed for servicing. Supplementary multiplier sections increasing testing capacity from 200 circuits to 600, 1200 etc.; remote control units; and miscellaneous accessories are available. DIT-MCO Inc., Kansas City, Mo.

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High Speed Angle Centrifuge Accessory

Special Rotor for testing semiconductor products has been added to the accessory list of the CSI High Speed Angle Centrifuge. Designed with three testing capacities, 4, 6, or 8 places, the rotor enables the centrifuge to test transistors in accordance with MIL-T-19500A, "Transistors, General Specifications for". Custom Scientific Instruments Inc., Kearny, New Jersey.

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WORTH FILING

Sheath Connectors Bulletin

A complete line of one-piece and two-piece compression sheath connectors for shielded or coaxial cable is described in a new 16-page catalog. Both the one-piece Uniring and two-piece Hyring connectors are used for terminating, grounding or tapping; are available insulated or uninsulated; are color-coded for easy size selection; and are crimped to cable by any one of seven different ratchet or pneumatic hand or bench tool. Catalog includes complete listings, dimensional drawings, assembly procedures, tooling information and related Burndy products.

Source: Omaton Division, Burndy Corp. Norwalk, Conn.

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Strain Gage Carrier Amplifier

Virtually eliminating the necessity of strain gage signal amplification by such bulky auxiliary equipment as voltage-stabilized d-c amplifiers, new strain gage signal amplifier converts strain gage voltages to levels high enough to be telemetered without additional amplification. Operating from the typical airborne 28-volt d-c supply, the units provide an output of 0-5 volts d-c which is exactly proportional to the quantity being measured—pressure, acceleration, structural strain.

The unit converts the 28-volt d-c supply into a pulsating 10kc square wave, which is modulated by the transducer and amplified to the 0-5 volt range. A demodulator unit returns the amplified signal to direct current for the output. Frequency response is virtually linear up to 2000 cps and the unit provides infinite resolution. Introduction of span and zero adjust adds to the amplifiers' versatility.

Transistorized throughout, the new amplifiers will sustain vibration up to 35g in any axis with frequency as high as 2000 cps without change in response or accuracy making them ideal for dynamic test installations on aircraft or missiles. Having an operating temperature range of −65°F to 160°F, the new amplifiers are expected to provide test engineers with far greater freedom in selection of system components and with instrumentation weight reduction in airborne test programs. Statham Instruments, Los Angeles, Calif.

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Infinite Resolution Potentiometer

True "slide-wire output" potentiometer, available with either three or ten turns and with resistance from 2 to 250 ohms/turn, utilizes a unique design in which a formed noble metal alloy wiper brush continuously contacts a single, helically wound, length of noble metal resistance wire. Use of a non-metallic coil form, in conjunction with widely spaced turns of wire, results in low inductance and capacitance effects in a-c circuits. The infinite resolution and exceptional linearity of the potentiometer make possible a simple solution to the "hunting problem" common in high resolution servo systems. Tradenamed Spiralpot, the pot has sleeve bearings, an indexing pin, and a black anodized aluminum case. Other applications are found in computers, control systems, and high resolution indicating systems. G. M. Giannini and Co., Pasadena, Calif.

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MANAGEMENT

Oliver G. Haywood, Jr.
CONTRIBUTING EDITOR

"Fail Safe"

MANAGEMENT CONTROLS

Before becoming Vice President of Emerson Electric Manufacturing Co. of St. Louis, Mo. and General Manager of their Electronics and Avionics Division, Oliver G. Haywood Jr. was Manager of Waltham Laboratories of Sylvania Electric Products, Inc. He has a B.S. from the United States Military Academy, an M.S. from Harvard and a D.Sc. from MIT. His last military assignment was with the Air Research and Development Command where he organized and headed the Office of Scientific Research. He has served at Los Alamos Scientific Laboratories and with the Atomic Energy Commission. He has worked in the research, development and production of missile systems, avionics, electronics, fire control systems, air frame structures, computers, rocket launchers, instrumentation and related assemblies of airborne, shipborne and ground base systems. Here is Dr. Haywood's first column. His future columns will include: Executives—Time Study Yourselves; The Role of Management Is to Manage; and Decentralization of Salary Administration Without Loss of Control.

The heart of a guidance system, whether of a missile or an automatic factory, is the feed-back of data as to how the unit is working to the control mechanism directing the unit. System accuracy degenerates with time. Accuracy may be improved by a second feed-back loop, a superimposed monitoring circuit which periodically corrects errors in the primary system. The gain is greater accuracy; the penalty is increased circuitry and thus greater probability of component failure. The maximum gain with the minimum risk can be obtained by a monitoring circuit which "fails safe"—it acts only to change, and if malfunction occurs in the monitoring circuit or if for any other reason the monitoring circuit gives no signal, the primary circuit continues to operate on its own feed-back loop.

This monitoring circuit may well serve as an electronic model for Management. Management should establish policies and procedures to assure that it "fails safe".

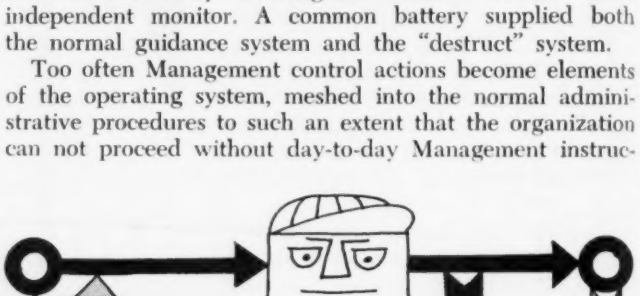
FUNCTIONS OF MANAGEMENT

The essential functions of Management are to plan the objectives of the group, to establish the structure of the organization, to assign the key people and allocate other necessary resources, and to establish controls—controls to assure that these people in this organizational structure with these resources can and do accomplish the group's objectives. The only day-to-day operating function of Management is control. The control system should be set up as a "fail safe" monitor—if Management does not act, the organization should continue on the path it is going. (I use Management throughout this article with a capital "M", to signify that I mean to exclude first and second line foremen and office supervisors. Such supervisors may properly be part of the primary operating organization.)

The purpose of organizations, and more specifically of Managements, is to get something done. Controls are essentially negative—in themselves they accomplish nothing. Controls should point the way and keep people on it without impeding progress along the way.

A "fail safe" Management control system can not be an element of the basic or routine administrative system. A few years ago a guided missile hit the beach in Florida after it failed to destory itself upon "destruct" signal from the monitoring system. The monitoring circuit failed to act when needed. Why? Investigation revealed it was not an independent monitor. A common battery supplied both the normal guidance system and the "destruct" system.

Too often Management control actions become elements of the operating system, meshed into the normal administrative procedures to such an extent that the organization can not proceed without day-to-day Management instructions or clearances. Engineers and engineering managers have devoted keen analytic thought to the design of control systems. It is time for Managers to look with corresponding criticality at themselves as components of the most complex control system of all—the management of men.



PERFORMANCE TEST FOR MANAGEMENT

A busy executive should apply the experimental approach of science to himself. Let him as he approves or amends each paper that reaches him, put it in one of two piles on his desk. At his left let him place those action papers for which his approval, disapproval, or amending instruction changes the assignment of a key man, or the organizational structure, or the group's objectives—Management policy papers. At his right let him pile those action papers that do not affect in any significant way the assignment of key personnel or resources, the organizational structure, or the group's objectives. These are papers he considers he must approve to maintain Management control or that he acts upon because he has never considered having them not routed to him. Action cases that reach him by telephone or visitor should be piled figuratively in the growing left and right hand piles on his desk.

At the end of the day, if the left hand pile of policy papers on the executive's desk is high in comparison with the right, he is truly performing the role of Management. He will also find that he has few papers on his desk, each representing a major decision.

The average executive, however, will find a high stack of papers at his right—the non-policy pile. A further analysis is now required: are there many disapprovals or amendments? If so, the executive has taken over the role of his lower-echelon supervisors. He has permitted his position to degenerate from that of Management to that of operations. He has become a part of the basic administrative loop rather than the monitoring control. Perhaps the answer lies in the capabilities of his subordinates. But, unless it is a temporary situation, this is just a reflection on his own ability as a Manager, for his first responsibility is the selection and training of his key subordinates. Frequently a Manager remains involved in operating decisions after promotion to a higher level. He retains reins of control he formerly and properly held. The Works Manager just promoted to Vice-President for Manufacturing knows more about the Work Manager's job than does his successor in it. He finds it difficult not to assist with his experienced judgment on all matters reaching the Works Manager.

I once faced a similar situation and realized that I was not letting go, adversely affecting both my own efficiency and my subordinate's. I decided there was practically no action he could take that could not be corrected the following day if he were in serious error. So I stopped all papers he was sending me for approval, asking instead that he send me a carbon copy of such papers after he had cleared them. I saw carbons of many papers I would not have signed—I do not like "utilize" as a synonym for "use" or "enthuse" for "feel enthusiasm" and have other idiosyncracies like most human beings. But one does not retract a paper because of a disagreement in precise wording if the paper accurately conveys a correct decision. During several years of using this procedure, I have found it seldom necessary to withdraw a paper approved by a well-instructed subordinate acting within the scope of his delegated authority. Moreover, rare corrective action caused no embarrassment. In the few cases when I have had to telephone a high company official or an outside company to say that we had let a letter get out the day before which we would have to withdraw, it was accepted quite readily and the letter was normally returned unopened. A telephone call the following day usually reaches anyone before the letter. I recommend this action to any Manager interested in developing his self-discipline in keeping out of the sphere of authority he has delegated.

So much for the executive who finds in analysis of his right hand pile of non-policy papers that he is taking over the jobs of his subordinates. More frequently, the analysis of these non-policy papers will disclose that they consist almost entirely of approvals. The Manager is expending valuable time as a high-paid rubber stamp. The papers are coming to him not for his approval but for his information. An action paper is seldom designed for the efficient communication of information to Management. Furthermore, even if it is determined to be the best information document, a carbon copy to the executive would serve as well

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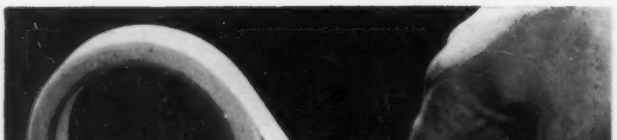

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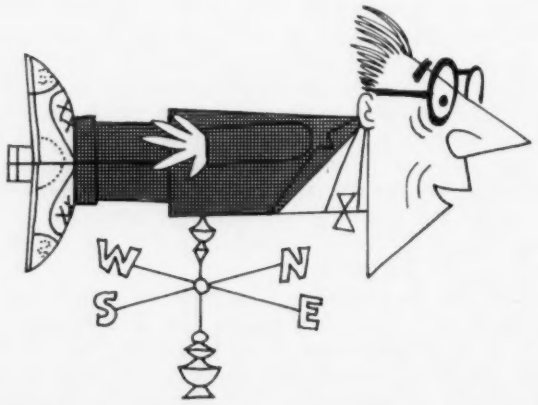
as the original: it would supply the same information and at the same time it would add no administrative expense, permit timely executive action to amend or disapprove in the rare cases when such is necessary, expedite the administrative process, keep it moving ahead when the executive is absent or temporarily overloaded, clarify responsibility for decision, and most important of all develop subordinates in the making of final judgments.

There seems to be a common belief that, no matter what other authorities may be delegated, salary changes require personal and high-level executive approval. I am convinced that the most inefficient, most inequitable, and most expensive to the Company of all salary administration systems are those that require individual salary approval by executives so high in the organization that they are not in a position to appraise personally the individual's performance. This subject, however, justifies fuller treatment in a separate article.

MANAGEMENT IS A FULL TIME JOB

Regardless of whether the Manager handles many non-policy matters a day because he feels he can not depend on his subordinates or because he desires to see such papers to keep himself informed, the underlying principal and often unconscious reason for his doing so is intellectual laziness. Managers are dynamic by nature, or they would not be Managers. They have to keep busy. Policy decisions are hard to make. What better way to postpone the difficult thinking required for planning and policy creation than to spend a ten-hour day on routine matters, always justified by pressing urgency. I have heard a company president say he did not have time for planning beyond the next quarter. I have heard a division general manager complain that his managers had more time for planning than he did. Who but the Manager himself is responsible for allocating sufficient of his own time to the most important elements of his own job. Does the Manager really have to handle so many details himself? Or has he simply found it less mentally taxing to bury himself in these details rather than in analysis of the over-all significance and rationale of these actions in order to enunciate policies under which others may make decisions?

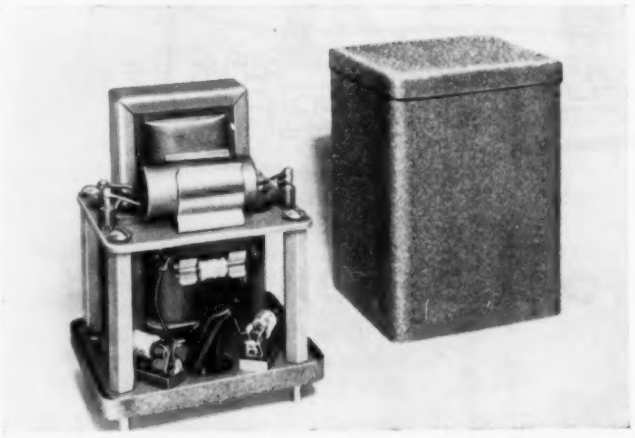
In an infantry platoon the lieutenant does not carry a rifle. The directed fire of 50 men is more effective than the undirected fire of 51. The Manager's job is too important for him to permit himself to stand on the firing line.



The role of the Manager, like the monitoring circuit, is not to approve but to change, and furthermore to change in the correct direction—the direction of the future. To do this, Managers must be informed—informed to the limit of individual endurance, absorption capacity, and time avail-

able after devoting adequate time to creative thinking. Other than for regular inspection, occasional correction, and necessary inspiration, Managers should not be needed to keep the key personnel in the established structure driving toward announced objectives.

Policy and planning functions of Management require full-time attention. Management must remain out of normal administrative circuits so that it can act, when it does act, with deliberation. Management controls must "fail safe", for when Management acts there is no monitor. Should Management become an integral part of routine administrative channels, there remains no monitor and the organization, like the electronic model, will degenerate with time.



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WORTH FILING

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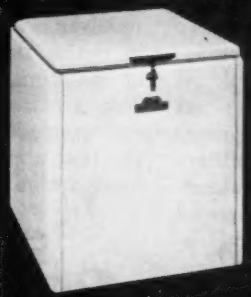

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CIRCLE 10 ON INQUIRY CARD

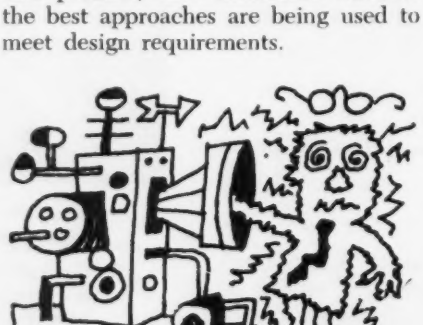
DESIGN TIME SAVER

DESIGN REVIEWS FOR RELIABILITY

Here is an easily administered design review program used successfully by RCA's Missile and Surface Radar Department to achieve greater realiability of systems and components and at the same time cut costs.

The need for more mature circuit design has been emphasized by many for some time. Considerable blame for unreliable equipment has been placed on the design engineer. Also there has been a great influx of new engineers into the expanded field of military electronics causing increased administrative responsibilities for experienced engineers. Consequently, electrical design work is often performed by engineers having insufficient experience especially in factory follow and field experience. The average length of experience for most engineering organizations at the design level is very short. And every project is a rush program. These factors of unreliability were pointed out by Harold C. Bryson Jr. of Radio Corporation of America at the recent Reliability Conference in Washington, D. C. Combined with the increased complexity of weapon systems, he said, they have created a need for a program to guide and monitor design work. Such a program has been developed by RCA over the past four years for reviewing electrical circuit designs in its Missile and Surface Radar Department, Bryson stated.

The purpose of this program he said is to bring to bear on each design conceived the cumulative knowledge of engineers having extensive prior experience with the types of circuitry involved. The goals, he said, are to minimize the possibility of repetition of errors made in previous designs, assure a more reliable and reproducible end product, and determine whether the best approaches are being used to meet design requirements.



To achieve maximum benefits from these reviews, Mr. Bryson said, they must be conducted at intervals during the design cycle when it is most feasible to effect changes. The design review cycle consists of a preliminary review during the study phase, a major review of the detailed design, and a final review of the operating equipment. Most common are circuit reviews, mechanical reviews, human engineering and wiring reviews, and systems or logic reviews. Review of logic diagrams or block diagrams is normally outside the scope of the circuit design review committee, except when they are considering circuit requirements.

THE DESIGN REVIEW CYCLE

Mr. Bryson suggested the following design review cycle of procedures used at RCA to make best use of time allotted to a review program.

Hold Preliminary Reviews when new designs are in the planning stage, usually after a block diagram or logic diagram has been established in detail and tentative circuits have been selected to fill these blocks. For example, the feasibility of some new circuitry that has been breadboarded may be questioned.

During the preliminary review:

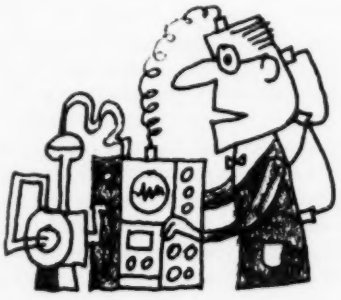
- Discuss the circuits tentatively selected for use or development.
- Discuss the necessity for the use and specifications of special parts, since these items are usually troublesome to procure, have long delivery cycles, questionable reliability, and are difficult to second source.
- Question whether proven parts and circuits are available, and encourage use of circuits and parts that are common to the system being designed where possible
- Discourage handbook engineering and do not enforce use of available circuits, but let the designer examine carefully what is available and make his own analysis as to suitability for his purposes.
- Use "standard circuits" only as de-

sign guides.

- Discuss whether specifications are complete or firm. If they are incomplete or vague, suggest steps to be taken by the project engineer, the systems engineer, or the design engineer, individually or collectively, to develop firm specifications.

Accuracy, stability, degree of regulation and other requirements, Bryson said, can make an enormous difference in circuit complexity. The order of magnitude of circuit performance must be known even though the final requirements are not.

- Formulate some feasible plan for design within target specifications so that later specification changes will cause only minor circuit modifications, since it is not uncommon for specifications to change as a project progresses.
- Consider also, how it can be demonstrated that a sub-system will perform properly when completed and tested—what simulation equipment is needed for engineering test, or must be built in for field maintenance. Bryson pointed out this test equipment may be harder to produce than the end product, because its accuracy requirements may be tighter. It is difficult, he said,



to allocate test and analysis time for a sub-system after it is connected in an overall system and system tests have started. It is also difficult to perform the analysis in the system unless means to separate the errors of the different sub-systems are available.

"In many cases," Bryson said, "preliminary reviews have resulted in equipment simplifications, considerable standardization, more practical specifications and an earlier start on special part design and other long range problems. Another result has been to knit the sub-system project team closer together. In some extreme cases problems have been highlighted which required rescheduling of the design task and assignment of more manpower for further study, advance development prior to product design, or parallel efforts toward a better solution."

Prepare for and Conduct the Major Review, the second phase in the design review cycle at the completion of breadboard testing.

- Let the leader of the design group

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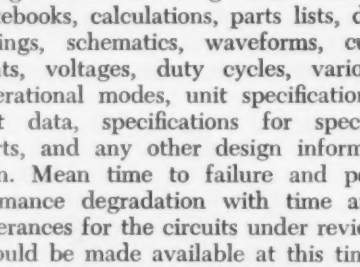
FOR MORE INFORMATION CIRCLE NO. 4 ON INQUIRY CARD

determine when the design is ready for review.

- Prior to the review, give to each member of the review committee a brief technical write-up including schematics, block diagrams, and test results.
- At the review meeting, present all design data including work sheets, notebooks, calculations, parts lists, deratings, schematics, waveforms, currents, voltages, duty cycles, various operational modes, unit specifications, test data, specifications for special parts, and any other design information. Mean time to failure and performance degradation with time and tolerances for the circuits under review should be made available at this time.
- During the major review, attempt to assure that everything possible has been considered to make the equipment perform its intended function reliably. Don't attempt to redesign at the



review. Refer questionable areas back to the designers for further investigation. Mr. Bryson warned that the major review is the last opportunity to initiate any major rework or specification change before final drafting and construction of engineering or pre-production models.

Conduct the Final Review of subsystems after completion of system and environmental tests. There is usually an accumulated operating time of several hundred hours on a sub-system before this review occurs.

The final review is concerned with what happened during testing and what follow up work should be done. Part failure reports and carbon copies of the equipment logs will have been accumulated and investigated during testing and some corrections will have been made.

Review all such changes to the original circuits and get answers to the following questions:

- Were any changes made in one unit to compensate for deficiencies in another?
- Were the test points adequate for troubleshooting?
- How long did it take to find any troubles?
- Can we reduce the down-time required for trouble-shooting?
- Were the set-up and calibration procedures adequate and was simulation equipment good enough?
- How stable was the system?
- Did the equipment meet specifications without strain or was there some marginal operation?
- Are there any safety hazards which should be corrected?
- Are there any fail safe features which should be restudied?

In general discuss any factor relating to reliability or reproducibility.

Mr. Bryson pointed out that the final review leads to product improvement and highlights needed changes before shipping and further production. The final review thus investigates the end product performance. Its primary goal is to obtain an overall view of the equipment operation to be expected during the production cycle and field use. It also serves as a check on the efficacy of prior reviews, he said.

ADMINISTRATION OF REVIEWS

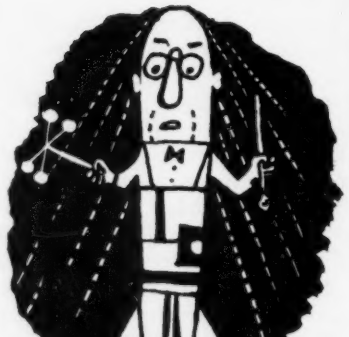
Mr. Bryson pointed out important factors in administration of design reviews by describing how the RCA Missile and Surface Radar Department conducts its program.

They have a central design methods group that conducts the majority of the electrical design reviews. In each design area, a permanent design review coordinator assists in coordinating reviews and conducts reviews when required.

The chairman for each review or series of related reviews is a member of the design methods group, or is the area coordinator. This arrangement, Mr. Bryson said, gives support to the central activity during periods of overload. There have been as many as 16 design reviews in one week, which required six chairmen, he said. Such a situation arises because design reviews must be held when the designer is ready.

The other committee members include the leader of the design team, the circuit designer or designers including technicians, a circuit specialist, a member of the part reliability and application group, the cognizant project engineer, and the systems engineer.

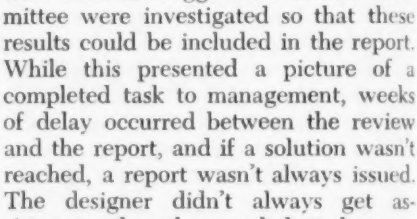
RCA includes design review in the project schedules for planning purposes, but they don't hold reviews just to meet schedules. Reviews are cancelled or postponed at the discretion of the designer, design leader, or chairman, if the design work is incomplete at the schedule review date. Since technical information is distributed several days in advance of the review to the committee members for study, gross design or specification faults are



sometimes discovered without need of a review. Reports of reviews are made promptly.

When the program first started at RCA, Bryson said, it was customary to write a complete technical report and wait until all suggestions of the committee were investigated so that these results could be included in the report. While this presented a picture of a completed task to management, weeks of delay occurred between the review and the report, and if a solution wasn't reached, a report wasn't always issued. The designer didn't always get assistance when he needed it because management didn't realize the need for assistance. Finally, the number of reviews conducted became so great that it became necessary to streamline the whole reporting system. A report is now issued whether the design is approved or not, in an outline form with a summary on the cover sheet.

During a preliminary review, the committee reports either that the present plans and specifications seem feasible or that more study is needed, with details of the deficiencies.



During the major or a final review, the committee may approve the circuitry or tentatively approve it pending further investigation in which case the report is amended and reissued when the investigation is complete. If it reports major rework is required the unit is reviewed again at a later date. The committee also may report that the circuitry is acceptable but that product improvement is desirable. The committee makes no effort to redesign at the review. It refers questionable areas to the designers for further study.

Management makes all decisions re-

garding design progress and hardware after consideration of the overall status of the project. For example, one equipment had about 40 different types of modules. Two were found to be marginal during the major design review. It was decided to build a limited number of these modules so that system debugging and testing would not be delayed. However, redesign work was done in parallel. During the latter part of the system test, replacement modules of improved designs were completed and installed. Systems tests were then completed and the equipment was shipped.

ATTITUDE OF ENGINEERS TOWARD DESIGN REVIEWS

During the build-up of the design review program at RCA, Mr. Bryson said, most of the experienced product design engineers were favorably inclined toward it but a few felt it was a reflection on their professional integrity. Some engineers with extensive research and development experience, but with no product design experience, couldn't understand the need for such a program. Some of the younger engineers felt that design review was a sword held over their heads. It was necessary for the design review activity to sell itself to all these engineers as a worthwhile service. "The atmosphere of the review should not be that of a courtroom," Bryson warned, "and obviously anyone with an attitude of superiority shouldn't be on the review board. The committee members must be willing to discuss their own past mistakes. The review is not a police action, nor is it a design by committee; it is a friendly give and take discussion. The sole interest of the committee is to try to assure good equipment, without relieving the designers of their responsibilities or opportunities to exercise their ingenuity."

RESULTS OF REVIEWS

Summarizing the effectiveness of RCA's review program, Mr. Bryson said that in the beginning of a project about one-third of the reviews result in some specification changes. Major reviews have indicated that about 10% of circuit designs require major rework and about half require minor modifications. Cost of the review program, he said, is considerably less than the savings accrued by correcting designs early in the design cycle; before final drafting, model work, system test, and factory work have been started. He pointed out that investigating malfunctions and correcting them after production has started is expensive.

AC Microammeter

AC Microammeter with high sensitivity, input impedance of 1 ohm and noise level of less than .03 microvolts permits low-level current measurements to be made without disturbing the circuit under test.

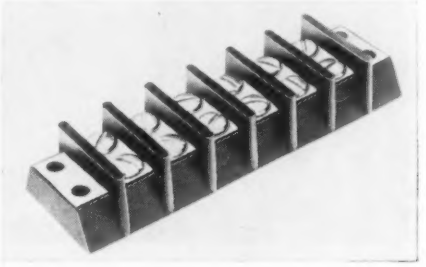
The instrument consists of a six stage transistor amplifier with stages arranged in pairs, and a large negative feedback around each pair. An oscilloscope connection provides for observation and measurement of current waveforms. Two input probes are provided. A clamp-on probe constructed of high permeability magnetic material with mating surfaces lapped to insure minimum leakage, permits rapid measurements of currents in the 300 to 100 microamp range.

An insertion probe which consists of a current transformer enclosed in a Mu metal shield to minimize stray magnetic pickup allows measurements to 3 microamps full scale with a noise level of less than 0.1 microamp. Additional stability and freedom from line voltage transients are obtained from a transistorized, regulated power supply. Quan-Tech Labs, Morristown, New Jersey.

Circle No. 165 on Inquiry Card

Molded Terminal Boards

Terminal Boards offer many new engineering design features such as: solid, insulated backs which eliminate the need for a separate insulating strip between screw end and ground; thicker, higher barrier design that increases creepage path by 12% over earlier terminal boards of the same size; molded-in conductors that assure positive, contamination-proof connections; molded-in inserts around the mounting holes that provide increased sectional strength at these critical points and eliminate the need for saddle plates; and greater current carrying capacity that enables the engineer to design more compact housings, boxes, chassis. General Products Corp., Union Springs, New York.



Circle No. 187 on Inquiry Card

Subminiature Neon Lamp

A fundamental problem in the application of small neon lamps to computer and matrix requirements, panel light, and indicating applications, has been their need of an external series resistor as a current limiting ballast. Without such a device these lamps quickly destroy themselves when the gas ionizes because excessive current flows.

To solve this problem, a new lamp has been developed that incorporates current control as an integral part of its internal structure. The glass tip of the lamp envelope is symmetrically hot formed to provide a less irregular shape than existed in earlier subminiature neon lamps. Electrodes longer than in previous lamps, provide an increased gas excitation area and more light. With a life expectancy in excess of 25,000 hours, the lamp generates practically no heat and consumes one tenth of a watt with a design current of only one mil.

Less than an inch in length and a quarter of an inch in diameter, the lamp has a midget flange base and is interchangeable in many assemblies and sockets with the Circon NE2C, NE2D, andNE2E; and incondescent lamp numbers 327, 328, 330, 331, and 338. Circon Component Corporation, Goleta, California.

Circle No. 157 on Inquiry Card

Radechon Storage Tubes

Radechon tubes, produced for use in computers, take information in the form of electrical impulses, store it, and when signalled to do so, read it back electrically. Westinghouse Electric Corp., Elmira, N.Y.

Circle No. 196 on Inquiry Card

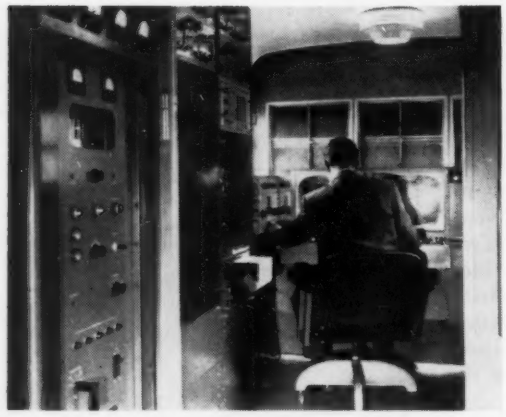
WORTH FILING

Fiber Glass Reinforced Plastics

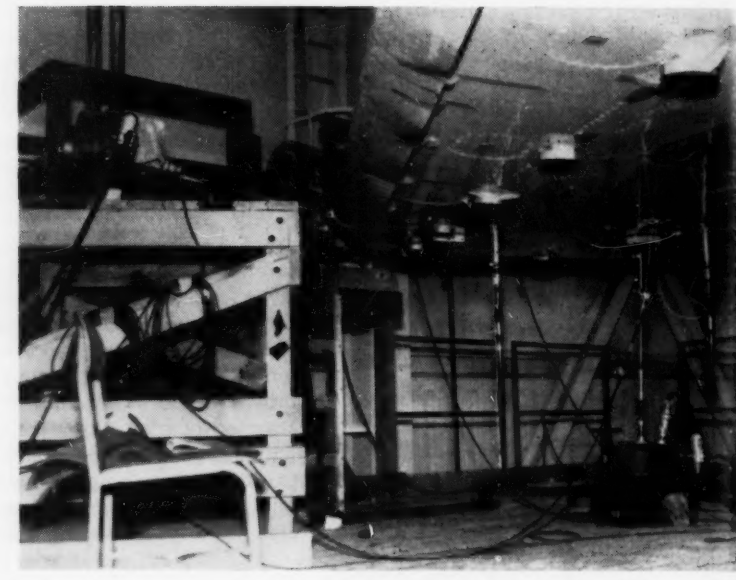
16-page catalog of materials for fibrous glass reinforced plastics lists fiber glass cloths, tapes, woven rovings, chopped strand mats, surface and overlay mats, continuous rovings, chopped strands and milled fibers, polyester resins, epoxy resins and hardeners, MEK and benzol peroxides, PVA films, pigment paste dispersions, diluents, accelerators and parting agents. Included are complete ranges of fiber glass fabrics and fibers, polyester and epoxy resins and catalysts, parting agents, pigments and other necessary supplies. Available sizes, grades and prices are shown under each material along with thumbnail descriptions of properties and recommended applications. Two pages of property tables for polyester resins and fiber glass cloths are included.

Source: Cadillac Plastic and Chemical Co. Detroit 3, Michigan

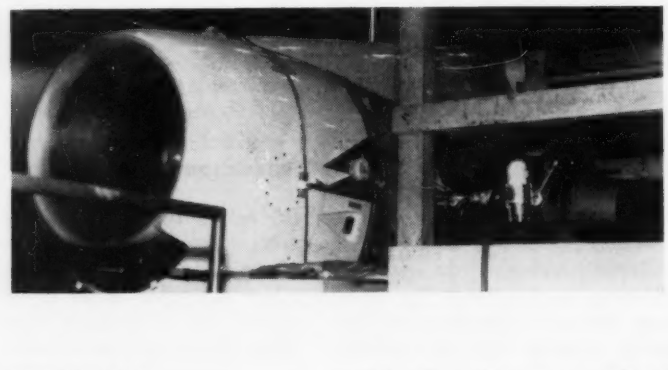
For your copy: Circle No. 226 on Inquiry Card



Control operator is seated at the main control station in the front of the trailer. Two seventeen-inch oscilloscopes in front of him permit monitoring information from the transducers attached to the airframe as he makes adjustments in shaker frequency by tuning the low frequency oscillator.



Two shakers excite the leading edge and lower surface of the DC-8 wing. Shaker force is transmitted to the aircraft structure through connecting rods. Trunnion mounting of the shaker provides a full 360-degree rotation of the force axis.



The instrumented nacelle provides response of the DC-8 engine area to horizontal excitation provided by a 70-pound force shaker. The glass airtrap on the side of the unit is for the compressed air line that cools the shaker coil. Air enters the side of the shaker and is exhausted through the vent at the rear of the housing.

MOBILE VIBRATION TEST LABORATORY

Jet "Shakedown" Flight in a Hangar

Tethered by dozens of cables and vibration shaker rods, the giant Douglas DC-8 jet airliner underwent its first major shakedown in a hangar at Long Beach. Information from sensitive pickups fastened to the plane was transmitted to a complete vibration testing laboratory on wheels, parked beside the ship. Marking a departure from cumbersome test methods involving piecemeal assembly of heavy laboratory equipment at the test site, the new trailer designed by Ling Electronics Inc., provides a complete, self-contained vibration generating and data reception center.

The purpose of the tests was to determine the structural vibrational characteristics of the complete aircraft. These characteristics determine how aircraft responds to applied dynamic loads during flight and landings.

The low frequency vibration tests are conducted by attaching "shakers" to the surface of the aircraft. These shakers are similar to the speakers in a radio. The difference is that their frequency range is lower, and instead of a paper cone to vibrate, they have an armature shaft with a 3-inch stroke, which may be transmitted directly to the airframe. Rods are connected to the shaker armature shafts, and then to the aircraft. As the shakers receive sine wave impulses from amplifiers, they transmit this power as vibrational force, applied directly to the aircraft. Each of the 12 shakers transmits a 70-lb. force at 0.25 to 300 cycles per second.

Power to drive the shakers is supplied by six matched 250-watt amplifiers which have a frequency response of 0.5 to 500 cps. A power distribution patch bay located in the rear of the trailer provides the means for assigning the amplifiers to the shakers. Various shaker-amplifier combinations are employed to generate the proper force characteristics on the structure.

Full control over the exciters is furnished at the operator's "S" panel located at the front of the trailer. Meters monitoring the shaker field voltage and field voltage controls are furnished for each of the twelve shakers. Each shaker is equipped with a separate gain control, and the gain of the entire shaker array can be adjusted through the master gain control.

Vibration induced in the airframe is picked up by the transducers. Monitoring the vibration transducers is accomplished through use of oscilloscopes and oscillographs. Two five-inch scopes act as the master oscilloscopes. Two seventeen-inch oscilloscopes are mounted directly in front of the operator and are slaved to the master scopes.

Signals from the transducers are fed to the oscilloscopes through two electronic switches. One switch samples twelve of the transducers, and the other switch samples twenty-four of the transducers. The twelve signals sampled by the one switch are fed to one scope, and the group of twenty-four signals sampled by the second switch are fed to the second scope.

Special bias controls on the oscilloscopes permit the operator to move the

signals from the transducers around on the scope to a desired pattern. For example, if transducers were attached to the nose, tail and each wing of the plane, the pattern of these signals could be moved on the scope to reproduce the shape of the aircraft. This allows the operator to identify the source of a signal immediately.

Permanent records of the transducer signals can be made by using the Sanborn four-channel recorder. Inputs to the recorder are located in the instrumentation patch board. Signals to the recorder are first fed to amplifiers which increase the signal level to a usable range for the recorder.

Technicians at the remote survey stations along the ship have two-way communication with the trailer operator. At each transducer junction box, there is a connection for the technician's combination headset-microphone line. This enables him to relay information from his station to the trailer without being hampered.

To permit determination of the damping characteristics of the airframe under test, a switch has been provided which simultaneously shuts down all the shakers. If this switch is thrown after the plane has been excited, the shaker forces are completely decoupled from the airframe and the structure returns to equilibrium under the actions of normal damping factors. This routine is used to determine the damping characteristics of the aircraft.

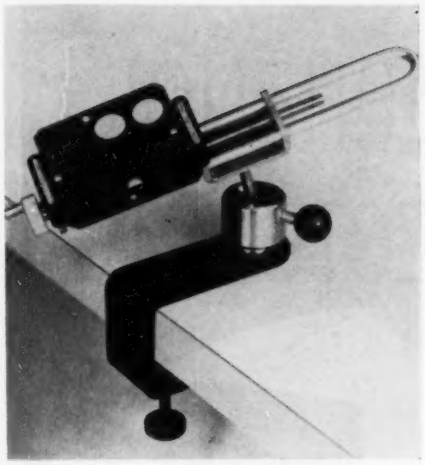
Signals to the shakers are generated by a low frequency oscillator tuned by the operator. Accuracy of the frequency setting is checked by using a decade type frequency counter.

All of the equipment is built into the trailer itself. Everything necessary for structural mode and dynamic vibration tests is carried. Except for a source of 440-volt a-c power and a supply of compressed air to cool the shaker coils, the trailer is self-contained.

Shakers are carried in roll-out drawers which pull out from the sides of the trailer. By hooking a portable power winch above the bin, each shaker can be lowered to dollies for transfer to the airframe. At the front and rear of the trailer are the cable stowage areas with power driven reels. These hold transducer and shaker cables.

Inside, felt-lined cabinets hold the sensitive transducer pickups, and other cabinets contain tools, spare parts and necessary accessories. The operator's section of the trailer is fully air conditioned. Within his reach are the main instrumentation panels and the controls that operate or monitor the equipment.

Circle No. 215 on Inquiry Card



Card-Holder and Vise

A portable fully-adjustable Tronic-Vise and Card-Holder holds printed circuit boards and small sub-assemblies firmly but gently, leaving both hands free for easy accessibility to either side. A hard corrosion-proof plastic ball housed in an aluminum socket locks in any position through 90 degrees. The Tronic-Vise opens up to 6½ inches, has rubber lined jaws and speed knob. The Card-Holder is adjustable and will take printed circuit boards from 3 to 10 inches wide and up to ⅛ inch thick. Sturdily constructed of heavy gauge cadmium-plated steel, the units have bases finished in dark gray wrinkle enamel. Flotron Industries, Inc., Inglewood, California.

Circle No. 201 on Inquiry Card

Epoxy Adhesive Pack Eases Repairs

Storage and mixing of epoxy resin adhesives, used in repairing honeycomb and other structures, is easier and free of contaminants with use of a new Adhesive Pack. The Pack consists of two clear plastic containers. A short length of plastic tubing connects one chamber, containing a glass ampoule filled with the prescribed curing agent to the other chamber containing the basic epoxy resin. To use, you break the glass ampoule and the agent runs into the adhesive chamber. A nylon mesh strainer prevents the transfer of glass particles to the adhesive. You mix the resin and agent by hand kneading in the sealed plastic chamber and upon completion cut the tube and extrude the adhesive by hand pressure.

The glass ampoule contains the proper amount of curing agent for the specified epoxy and eliminates errors. The Pack has a long shelf life, built-in safeguards against inadvertent mixing, and is small and light for easy portability and storage. Fenwal Inc., Ashland, Mass.

Circle No. 57 on Inquiry Card

WORTH FILING

Pilot Light Digest

16-page digest of condensed technical information on various categories of pilot light assemblies contains illustrated life-size units and gives data on lamps and their required voltages, front or rear mounting provisions, mounting hardware, insulation, type of lens holder, lenses and colors, terminal types, finishes, etc.

Source: Dialight Corporation
Brooklyn 37, New York

For your copy: Circle No. 211 on Inquiry Card

WORTH FILING

Measuring and Electronic Test Equipment Reports

8-page quarterly technical bulletin entitled "METERS" describes problems in instrumentation and measurement and suggests methods for overcoming them. It also explains the design and operation of high quality laboratory measuring devices such as Bar-Graph Oscilloscopes, frequency generators, microwave power meters, microvoltmeters, Tera-ohmmeters, power signal generators, slotted lines, reflectometers, impedance measuring diagraphs, reflecting galvanometers, fluxmeters, and a wide variety of other instruments and instrumentation systems.

Source: International Tel. & Tel. Corp.
New York, N.Y.

For your copy: Circle No. 58 on Inquiry Card

WORTH FILING

Ceramic Magnet Pulleys

4-page booklet describes the Indox V Permanent Magnet Pulley for tramp iron separation in belt conveyor systems, and explains efficiency achieved by "radial pole design" made possible by magnetic characteristics of Indox V —a ceramic magnet material.

Source: Stearns Magnetic Products
Milwaukee 46, Wisconsin

For your copy: Circle No. 72 on Inquiry Card

WORTH FILING

Instantaneous Voltage Regulators

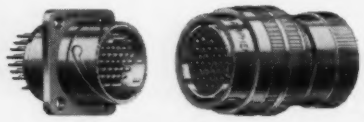
12-page bulletin gives complete ratings, outline dimensions, illustrations and prices on electronic automatic voltage regulators. Rated from .25 to 10.0 KVA for nominal 115 or 230 volt output, the regulators have no moving parts, instantaneous correction, excellent regulation and stabilization and minimum waveform distortion.

Source: Superior Electric Co.
Bristol, Connecticut

For your copy: Circle No. 230 on Inquiry Card

3 NEW AMPHENOL "E" CONNECTORS!

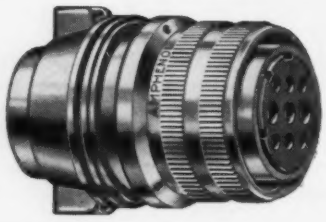
MINNI E



½ actual size

First miniatures to meet the "E" performance requirements of MIL-C-5015C. 5 shell types, 4 constructions, 5 shell sizes, 17 inserts.

STUB E



actual size

Smallest, lightest standard MS "E" MIL-C-5015C connectors. 4 shell types, 51 insert arrangements. Unitized rear grommet assembly.

*U. S. PATENT 2,419,018

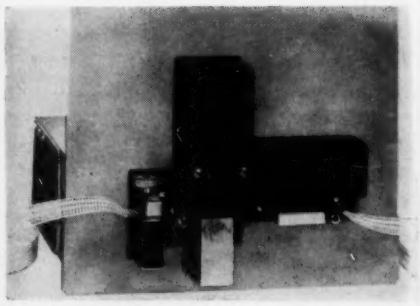
Real E

½ actual size

High temperature MS "E"-type connectors. Operating temperature of 400°F. continuous. Complete line. Removable Poke Home contacts* with braze or crimp terminations.

AMPHENOL

AMPHENOL ELECTRONICS CORPORATION
chicago 50, illinois



Tape Strip Reader

Transistorized perforated tape strip reader provides accurate and economical means for processing information into digital data computer systems. Suitable for rack or console mounting, the unit requires virtually no training for operation. Some design features are: character reading speeds up to 1000 char/sec, 3 millisec starting time, simple in-line threading, stop on STOP character and reads next character after start, 100 x 10^6 operation pinch roll, photo diode head reads any tape, reads 5,6,7 or 8 level tape with sprocket channel, ambient temperature up to 125°F with 10,000 hour life, not affected by temperature changes. Potter Instrument Company, Plainview, N.Y.

Circle No. 204 on Inquiry Card

Laboratory Reactor

Reactor permits a wide range of research and training in the nuclear field and provides nuclear radiation for important studies in engineering, biological and medical fields. Only eight feet high and eight feet in diameter, the laboratory reactor can be installed in any existing laboratory building without the addition of special facilities. It is low priced and can be constructed, installed and made ready to run at any location on a short delivery schedule. Contained in a stainless steel sphere or core about 16 inches in diameter, "fuel" for the reactor is a solution of uranyl sulfate, enriched to 20 per cent or more in the uranium 235 isotope. Nine beam tubes running through or adjacent to the core permit several experiments to be conducted while the reactor is operating. The reactor is controlled from a single console panel, and only one operator is required to operate the unit. Surrounding the core are four concentric cylindrical shield regions which attenuate radiations and moderate or "slow down" neutrons to shield reactor personnel from radiations. Atomics International, Division of North American Aviation Inc., Canogo Park, Calif.

Circle No. 199 on Inquiry Card
←Circle 25 on Inquiry Card

Univistor

Transistorized direct replacements for mechanical vibrators that plug into the vibrator socket convert an electromechanical power supply into an all-electronic power supply, with all the advantages of a transistorized unit: greater reliability, higher operating efficiency, longer operating life, cleaner output, elimination of electrical and mechanical noise, and elimination of moving parts and maintenance costs. The Univistor is an astable multivibrator used in conjunction with an external vibrator transformer to deliver a-c power output from d-c input. Since the external vibrator transformer is a part of the basic power supply circuit, the Univistor can be interchanged with a vibrator without any alteration in circuitry. Two germanium power transistors make up the basic switching element. The existing vibrator transformer is used to effect the switching. Universal Transistor Products Corp., Westbury, New York.

Circle No. 59 on Inquiry Card

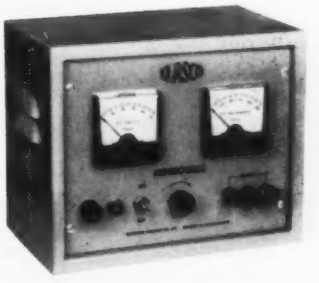
Zener Diode Substitution Box

Zeniac, a diode substitution box, offers a selection of eleven basic one watt silicon zener diodes covering the range from 3.6 to 30 volts, to aid the design engineer in rapid selection of zener diodes for experimental breadboard circuits. The decade-type substitution box is housed in a compact, easily portable unit which may be inserted into any breadboard circuit. A turn of Zeniac's selector switch rapidly determines the exact diode required. Substitution boxes have long been in use in the resistor, capacitor and inductor industries, where they have proved to be time and labor-saving devices, and Zeniac is a device of this kind. International Rectifier Corporation, El Segundo, California.

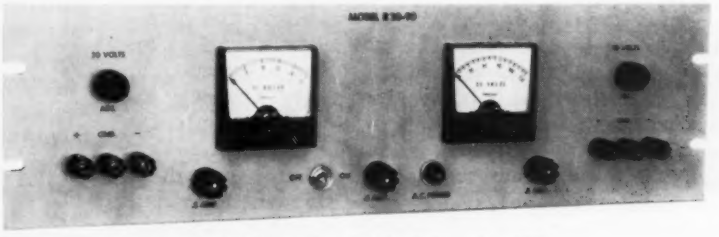
Circle No. 206 on Inquiry Card

power supplies

Transistorized • Transformer Cased
3 5/16 x 3 7/8 x 4 1/2 • Basic Price: $64 to $127



Lab Model • Basic Price plus $60



Rack Mounted • Basic Price plus $50

Elasco's MINISOURCE power supplies, fixed or semi-variable, are designed for use with transistorized circuits, instrumentation, computer circuitry, as bias supplies, or any application where good regulation of low voltage is required. They are available for either 60 cycle or 400 cycle operation, for any voltage between 5 and 50 volts, and at current ratings between 50 and 500 ma

INPUT: 105—125 V AC
REGULATION: better than 0.5%
RIPPLE: better than 0.5%
OUTPUT IMPEDANCE: less than 0.25 ohms, DC—100 kc
POLARITY: grounded or floating operation
TEMPERATURE: compensated from —10 to 55C
PRICE RANGE: Indicated below each unit

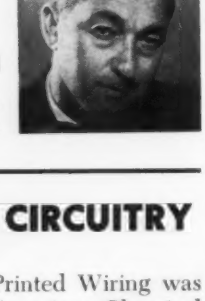
Send for complete catalogue

Elasco

ELECTRONIC ASSEMBLY CO., INC.
Five Prescott Street, Roxbury 19, Mass.
Highlands 2-1600

FOR MORE INFORMATION CIRCLE 26 ON INQUIRY CARD

STAFF COLUMNIST



David Bandel
Associate Technical Director,
TRACERLAB, INC.

PROGRESS IN PRINTED CIRCUITRY

A symposium on Chemical Aspects of Printed Wiring was held during the Spring Meeting of the American Chemical Society in San Francisco. The wealth of material presented at this symposium warrants a more comprehensive discussion than space here will permit. Papers read at this symposium will eventually be published in the open literature and will be available in full detail. This report is a summary of some choice items presented at the meeting.

Chemical Problems in Printed Wiring was discussed by E. B. Saubestre of Sylvania Electric Products. The chemical problems were broadly subdivided into two classes, those associated with the production of printed circuits and those associated with electrical performance.

Conventional resists, or stop-offs, are not entirely satisfactory. Difficulties in obtaining even deposition of resist are due mainly to roughness, unevenness and absorptive properties of the laminate boards. The most serious problem in resist development is pinholes and it is often severe enough to cause rejection of the finished wiring board. One way to get around the pinhole problem is to use solder resists. In this method, a reverse stop-off is applied and then solder is plated onto the laminate where the conductive pattern is desired. If there are any pinholes in the stop-off, the solder will be brushed away when the reverse stop-off is removed. Unwanted copper is then removed by etching in a medium that will not attack solder.

Many materials will etch copper at a useful rate. However, other requirements such as attack or contamination of the laminate have limited the field of useful etchants. Most generally useful etches are ferric and cupric chlorides. In particular, ferric chloride has been the most popular etching agent, producing highest rate of etching and longest bath life. A newly developed, constant regeneration etching bath based on cupric chloride, discussed below, will probably replace ferric chloride as the preferred etch. Nitric acid has been used as a copper etchant and has certain attractive advantages over usual chloride types. However, problems such as "run-away" reactions must be solved before nitric acid can compete with ferric and cupric chloride etches. Nitric acid etches also suffer from the same limitations as the chloride type with regard to build-up of cupric ions in solution. This results, eventually, in build-up of some insoluble cuprous oxide on the surface of the copper, progressively reducing etching rate. This problem of reduction in etching rate by copper ion build-up is common to most etching agents and progress in this field awaits a solution to this problem.

When solder is applied to the copper-clad laminate as a resist, chloride and nitric acid etches cannot be used. A chromic-sulfuric acid etchant must be used to maintain a chromate coating on the solder to prevent dissolution of the solder resist. Rate of etch with chromic-sulfuric acid baths is very slow and bath life is short. Splash etching increases the rate of etching but presents the usual difficulties: corrosion and health hazards and lack of close control of etching rate. Carefully selected oxidizing agents increase useful life of the bath to a considerable degree but do not effectively increase etching rate. Chief advantage of chromic-sulfuric acid etch is that it can be used to etch copper in the presence of solder, nickel, rhodium and certain other metals that may be plated onto the copper wires but much additional work remains to be done to make this type of etch commercially attractive.

Peroxysulfates have been used for many years for stripping copper from steel. Recently, this application has been extended to printed circuitry. While showing some promise,, there are certain problems presented by these etchants. Catalysts, usually mercury or silver ions, are necessary to obtain a useful rate of etching. Control of catalyst content is important; too low a catalyst concentration leads to low etching rates, too high a catalyst concentration leads to displacement plating-out of the mercury or silver onto the copper surface. Some types of laminate may be attacked by the peroxysulfate bath and some lamintes catalyze the decomposition of peroxysulfates to sulfate. Several advantages of peroxysulfate etches make them attractive, however. They may be used to etch copper at a fairly high rate in the presence of solder, nickel, rhodium, gold and silver, offering a combination of the more rapid etching rate of chloride etches and the selectivity of chromic-sulfuric acid etches. Also, peroxysulfate etches do not fume, splash etching is not required, sludge formation does not occur on aging and copper recovery is easily accomplished by cathodic reduction.

Another method of producing printed wiring is to lay down metallized patterns on unclad laminates. Metallized patterns can be laid down by metal spraying, conducting inks, metallic paints and plating techniques. Most attention has been focused on plating procedures, particularly on "electroless" or chemical reduction plating. Board preparation must be done carefully to obtain an adherent metallized film. Adhesion is one of the major problems. Experience over the past few years has shown that adhesion between laminate and metallized film is inadequate to meet rigid military requirements on a reliable basis. It has become usual practice to apply an adhesive to the laminate prior to metallizing. This complicates the problem by limiting the use of proper alkaline cleaning solutions and types of sensitizers. Better adhesives and methods of sensitizing adhesive coated boards are needed.

For silvering, acidified stannous chloride is the usual sensitizer. Anionic surface active agents and quinol have been used as additives for adhesive coated laminates. Organic tin salts, such as dimethyl or diethyl tin chloride, have been used as well. If coppering is to be used, precious metal salts such as gold, platinum or palladium chlorides are used as sensitizers. Ketones and the lower alcohols are satisfactory solvents. The most satisfactory method of silvering is to use a two-gun spray. One nozzle delivers the silver solution, the other the reducing solution. Laminated boards can be rendered conductive in a matter of seconds by this procedure. Silvering has two drawbacks in comparison to coppering. Removal of unwanted silver after the pattern has been defined is more difficult. More seriously, silvering has not been permitted in recent years in military applications because of the problem of silver migration.

Interest in coppering has grown recently. Choice of solutions must be made carefully to obtain catalytic reduction of the copper. Best results have been obtained with formaldehyde as the reducing agent in an alkaline tartrate copper solution. In this bath copper is itself a catalyst for the reduction and once a thin flash of copper has been obtained on a properly sensitized board, copper build-up continues, catalyzed by the copper initially formed. The principal problem in coppering baths is the tendency of copper to reduce to the cuprous state. Since most cuprous salts are insoluble in alkaline baths, this results in the

formation of an insoluble layer of cuprous oxide on the laminate and reduction ceases or leads to loosely adherent non-conducting films. Even under favorable conditions heavy coppering deposits tend to darken and become spongy or blistered in time. Under ideal conditions coppering solutions will deposit about 1 mil per hour of sound copper deposits.

Coppering has other serious drawbacks for commercial application. Although coppering solutions are designed to be catalytic it is nearly impossible to avoid the formation of metallic copper nuclei in the plating solution. Copper reduction will take place on the surface of these nuclei and the bath will be ruined by reduction of the copper bath to metallic copper. No satisfactory way has been found to lengthen the life of copper baths once this nucleation has begun. Additives and pH control help but lead to lowered copper deposition rates on the laminate. Coppering solutions presently in use must be applied by immersion only. No satisfactory spray method is in wide use at present. However, much work is being conducted to develop spray methods and there should be some commercially interesting copper spraying methods available soon.

"Electroless" nickel plating has some possibilities for printed circuit wiring. Acid baths can be used, which simplify the problem of choosing a suitable adhesive. Conventional nickel sulfate-sodium hypophosphite-organic acid buffers can be employed. Sensitizing methods are similar to those used for copper. One possible drawback for some applications is that a temperature of 90°C must be used. This may cause some difficulties with uncured or partially cured adhesives.

Electroplating of printed circuits is used for a variety of reasons. Copper plating is used to build up the conductor on plated boards. Resists such as solder and rhodium can be applied by electroplating. The procedures used are generally similar to conventional plating procedures, although it may be necessary to use lower current densities initially when the conducting film is thin. Alkaline plating baths, particularly those above pH9 attack most adhesives and wherever possible, high metal content, room temperature, acid plating baths should be used to minimize attack on the adhesive. Deposits from such baths tend to be spongy or dendritic. Copper, tin-lead, tin and rhodium may be deposited satisfactorily from such baths, gold and silver generally require cyanide baths. To minimize the adhesive problem with cyanide baths it is necessary to modify the conventional baths to increase metal content and reduce free cyanide content to permit operation at room temperature at lowest practical pH. Generally, it appears to be more feasible to develop new adhesive compounds rather than to modify plating baths and work along new adhesive lines should be more rewarding.

Electrical stability characteristics of printed circuits are closely tied in with chemistry of the process. Contamination, in particular, can cause leakage and bridging between adjacent conductors. Conductivity changes on the surface and in the bulk of the laminate can also occur. Laminates must be selected with the process requirements of circuit board production in mind, since susceptibility to contamination is dependent on the type of laminate, adhesives and metal deposition or etching procedures used. In etched boards, the principal source of contamination is etching solution residues, particularly when ferric chloride is the etchant. Residual electrolytes from cleaning, sensitizing, chemical plating and electroplating solutions is also a major source of contamination of printed circuit boards. Rinsing of etching residues is not simply a matter of being thorough. Consideration must be given to possibilities of ion exchange on the laminate surface and hydrolysis of etchant baths on dilution, particularly in the case of ferric chloride. Certain laminates have anionic ion exchange properties which will take up ferric ions as the anionic chloride complex. Rinsing causes hydrolysis and precipitation of iron hydroxide on the surface of the board which cannot be removed by further washing. This problem can be overcome by adding complexing agents to the rinses to prevent precipitation. Copper chloride etchants cause similar difficulties in contamination but the problem is not quite as aggravated as with ferric chloride. For ferric chloride suitable complexing agents are fluorides, EDTA, citrate, oxalate and phenols. For cupric chloride, ammonia, thiosulfate, thiourea, maleic acid, and thiocyanate are useful complexing agents.

The second part of this Symposium summary will appear in the August Issue.

Welded Metal Bellows

New welded metal bellows assemblies, custom engineered in a variety of sized and special metals are said to provide extreme accuracy and life over a wide range of critical operating conditions. Sizes range from ¼-inch to 18 inches, outside diameter.

The specially-developed bellows permits designs that are 25 to 50 percent smaller than conventional bellows, thus reducing the size of the assembly package.

Bellows assemblies are available in small or large production runs in metals such as AISI 300 and 400 series stainless steel, inconel-X, Ni-Span-C, titanium, zirconium and other weldable, non-ferrous materials. They may be designed with flat, spherical, stepped and other specially-shaped plates as thin as 0.003 inch with ±0.0001 tolerance.

Built of individually-welded plates, the new bellows may have many more convolutions per inch of length than conventional hydraulically-formed bellows. This, coupled with the precision inert gas welding process and the resistant characteristics of special metals used results in a precision-controlled effective area and a lower spring rate. Robertshaw-Fulton Controls Co., Milford, Conn.

Circle No. 51 on Inquiry Card

Air Cylinders

Return control units are built into the cylinder heads of a new series of air cylinders. The units, which are an improvement over earlier models requiring externally mounted control units, require only one inlet port. The series comprises: a hand controlled spring return cylinder; a cylinder with a rod that reciprocates automatically when air is brought to the unit; 2 automatic return cylinders that require only a single momentary pressure on the control unit to cause the rod to extend to its full length and return; and 6 cylinders that require mechanical, electrical, or pneumatic actuation of the control units for rod extension and deactuation for rod retraction. 8, 110, or 220 volt solenoids can be obtained for the electrically controlled units. A. K. Allen Co., Mineola, New York.

Circle No. 50 on Inquiry Card

WORTH FILING

Rotary Multipole Switches

20-page catalog describes standard tap, transfer, and selector switches with engineering data, electrical ratings, circuit and contact diagrams. Solenoid-operated rotary multipole switches and instrument and control switches are also covered.

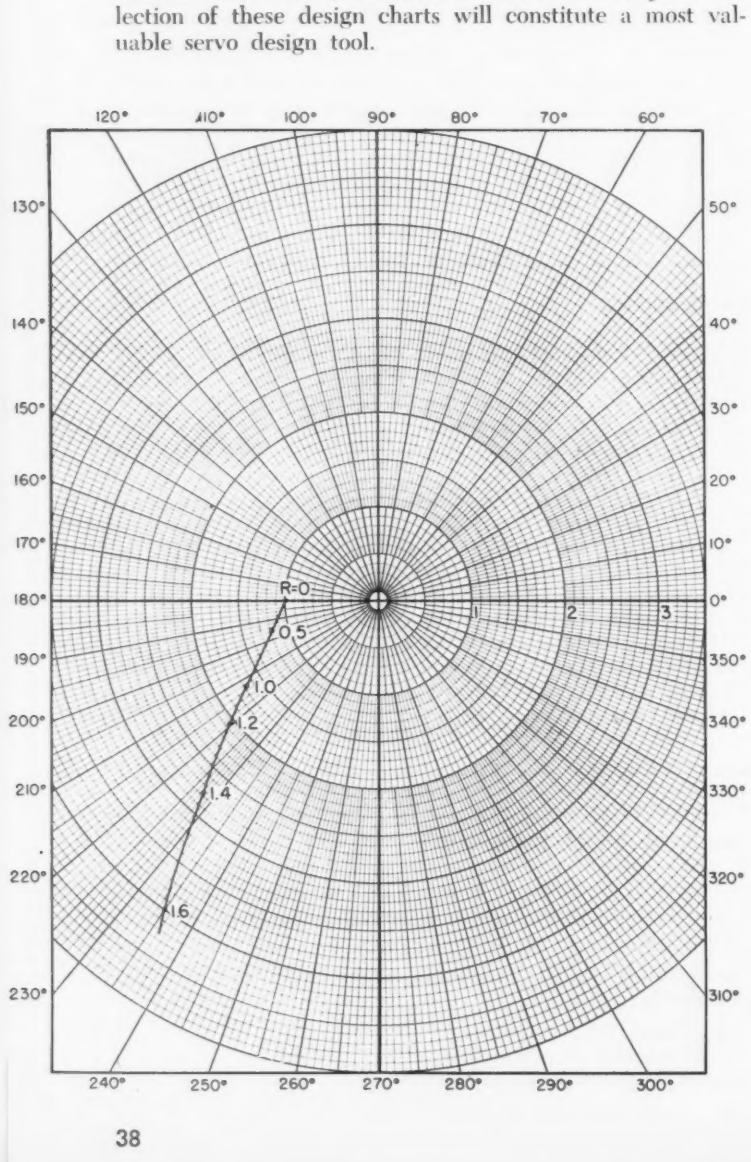
Source: Electro Switch Corporation
Weymouth 88, Mass.
For your copy: Circle 52 on Inquiry Card

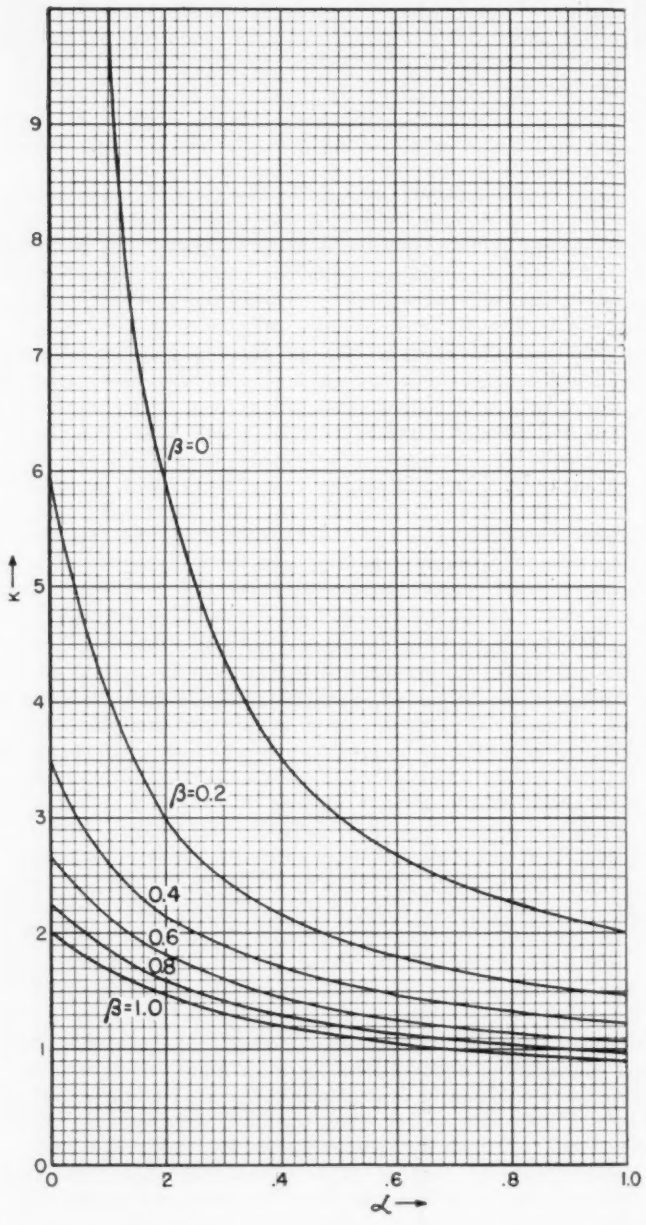
DESIGN TIME SAVER

Servo Design Charts

With this issue we start a series of time-saving servomechanism design charts presenting important design data in easy-to-use compact form with uniform notation. Many problems which formerly required tedious calculation by trial and error, may now be solved by inspection. The graphical presentation makes it especially easy to visualize the effects of varying individual servomechanism parameters and, consequently, to set tolerances.

Although individually self-contained, the Servocharts, which will appear from time to time in these pages, will ultimately constitute a balanced set, applicable to most servomechanism design problems. They will be supplemented with tabular information such as data on materials and gear accuracies, etc. Although many of the Servocharts will have never before appeared in print, some will be drawn from technical literature after simplification and standardization of the notation. We believe a complete collection of these design charts will constitute a most valuable servo design tool.





SERVOCHART I. Maximum Stable Loop Gain

$$G = \frac{K}{ju\,(1+ju)\,(1+j\alpha u)\,(1+j\beta u)}$$

Where j = complex operator, 90° shift
u = frequency on dimensionless basis
α, β = per unit values of 2nd and 3d time constants
K (as plotted) = max gain at 180° phase shift for stability

$$K = \frac{(1+\beta)\,(m+\alpha^2)}{m^2}$$

where $m = \alpha+\beta+\alpha\beta$,

u at nyquist point $= \frac{1}{m^{1/2}}$

SERVOCHART II. BACKLASH OSCILLATIONS

Polar Coordinate Plot of Negative Reciprocal Of Backlash Describing Function. If open loop frequency response curve intersects backlash locus, the servo will develop backlash oscillations. The peak amplitude of oscillation equals the minutes of backlash divided by R at the point(s) of intersection. The open loop frequency(s) at the intersection(s) determines the oscillation frequency.

Servochart I indicates the maximum stable open loop gain for a type I servomechanism with three time constants. The transfer function in general form is

$$G = T = \frac{K_v}{p\,(1+pT_1)\,(1+pT_2)\,(1+pT_3)}$$

This expression may be reduced to dimensionless form in terms of frequency by the following substitution of variables:

Let $P = jw$
$wT_1 = u$
$T_2\ T_1 = \alpha$
$T_3\ T_1 = \beta$
$K_v T_1 = K$

The transfer function becomes

$$G = \frac{K}{ju(1+ju)\,(1+j\alpha u)\,(1+j\beta u)}$$

This equation may be solved for that value of u yielding a 180° phase lag for G_1 which value may then be substituted back into the equation. For borderline stability, $G = 1$. Therefore K may be determined for this condition as a simple function of α and β. The servochart shows this function as a family of curves.

In a specific problem, simply determine α and β as the ratio of the secondary time constants to the primary time constant. The servochart will directly indicate K or K_vT_1. If the primary time constant is known, the theoreical maximum servo velocity constant is determined. It is common practice to allow a factor of safety of about 2 in setting this velocity constant.

The servochart is particularly useful in estimating the effects of residual time constants on the stability of simple systems.

Servochart II° is a polar coordinate diagram which is useful in determining the possibility of oscillations occurring as a result of backlash in the gearing. The type of shaping of the frequency response curve for an adequate margin of stability is easily seen. It may be shown by plotting that a simple servo having the transfer function

$$G = \frac{K_v}{p\,(1+pT_m)}$$

will not oscillate if $K_vT_m < 3.046$. The occurrence of oscillations in the ideal (frictionless) case will not depend upon the amplitude of the backlash. However, in real systems, the presence of friction is especially effective in damping backlash oscillations.

°The material for this chart is derived from a paper by N. G. Nichols, Backlash in a Velocity Lag Servomechanism, AIEE Paper 53-394, November, 1953.

WORTH FILING

Dall Flow and Venturi Tube Design Manual

Simplified formulas and tables for answering problems pertaining to selection of proper throat size and calculation of head loss in Dall flow tube, Venturi tube and Venturi nozzle applications are given and illustrative examples of formula applications are worked out to determine such economic factors as the pumping cost per year for differential producers under typical conditions. The bulletin also contains dimensional tables, capacity tables, and performance charts.

Source: B-I-F Industries, Inc.,
Providence, R. I.

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Aircraft cable is strung with spherical steel shells in a rigid or flexible housing sealed with "O" rings. 3" standard bend radius. ¾" minimum bend radius.
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Positive remote controls for actuating mechanical, hydraulic or other devices. Eliminate bell cranks, pulleys and dual cables. Patented U. S. A. All world rights reserved. Send for ENGINEERING MANUAL giving detailed prints and complete specifications covering materials, finishes, capacities. Please address Dept. EMD 58.
SOUTHWEST PRODUCTS CO.
1705 SO. MOUNTAIN AVE., MONROVIA, CALIFORNIA

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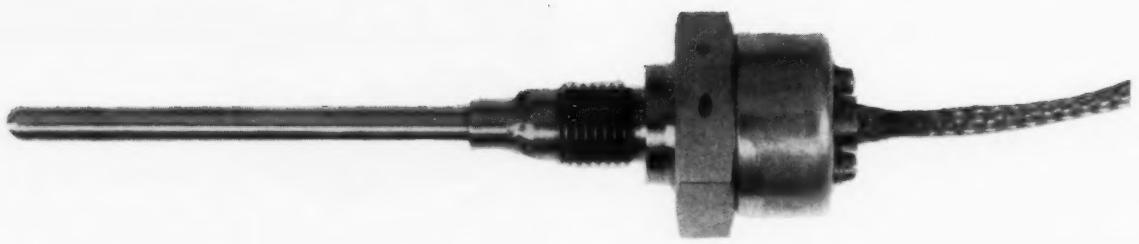

PLATINUM RESISTANCE THERMOMETERS

in temperature measurement, telemetry, and control

Here are descriptions of the various types and characteristics of platinum resistance thermometers and all information you need to use these transducers in a variety of bridge circuits and control systems. Engineers at Trans-Sonics, Inc., Burlington, Mass., furnished the information and data.

Need for fast and accurate temperature sensing elements in fields of measurement and control is increasing steadily. In addition, penetration of outer space with missiles and manned aircraft heightens requirements that temperature transducers be rugged, compact, and capable of producing large signal outputs without amplification. Platinum resistance thermometers meet all of these needs and are easily adapted to the measurement of the temperature of gases, liquids and solids.

I. Platinum as a Temperature Standard

Since 1871, when Sir William Siemens suggested that the change in the electrical resistance of platinum with temperature could be used in pyrometry, platinum resistance thermometers have become one of the most reliable means of temperature measurement. In 1886, H. L. Callendar proposed an equation relating the resistance of platinum to temperature. This equation has become the basis for universal temperature standards which relates the International Temperature Scale to the platinum resistance thermometer for temperatures above 32 degrees F. Because of their ability to measure temperatures to a remarkable accuracy of 0.00018 degrees F, platinum resistance thermometers are used to establish the International Temperature Scale.

The important Callendar Equation can be written in the following quadratic form:

$$t = 100\left[\frac{R_t - R_o}{R_{100} - R_o}\right] + \delta\left(\frac{t}{100} - 1\right)\frac{t}{100}$$

where

t=temperature in degrees centigrade
R_t=resistance of thermometer at temperature t
R_o=resistance of thermometer at 0 degrees C
R_{100}=resistance at 100 degrees C
δ=constant of the thermometer (nominally 1.493) found by calibration of the instrument at the boiling point of sulphur.

About 1925, the Callendar Equation was modified to be used for temperatures below 32 degrees F. This was done by adding terms proportional to the cube and fourth powers of temperature. This equation, known as the Callendar-Van Dusen Equation, is:

$$t = 100\left[\frac{R_t - R_o}{R_{100} - R_o}\right] + \delta\left(\frac{t}{100} - 1\right)\frac{t}{100} + \beta\left(\frac{t}{100} - 1\right)\frac{t^3}{10^6}$$

where β is a constant of the thermometer (nominally 0.111) found by calibration of the instrument at the boiling point of oxygen.

II. Advantages of Platinum Resistance Thermometers

Because the change in resistance of platinum wire with temperature is accurately described by the mathematical relations shown in Section I., it is possible to predict with reliability the resistance of a platinum thermometer at any given temperature. In addition, and in contrast to thermocouples and thermistors, platinum resistance thermometers can be calibrated to a high degree of accuracy, have excellent stability over an extremely long time, are nearly linear in response, and have an extremely wide temperature operating range.

These considerations have led to the development by Trans-Sonics, Inc., of an entire line of platinum resistance thermometers specifically designed for use in missiles and

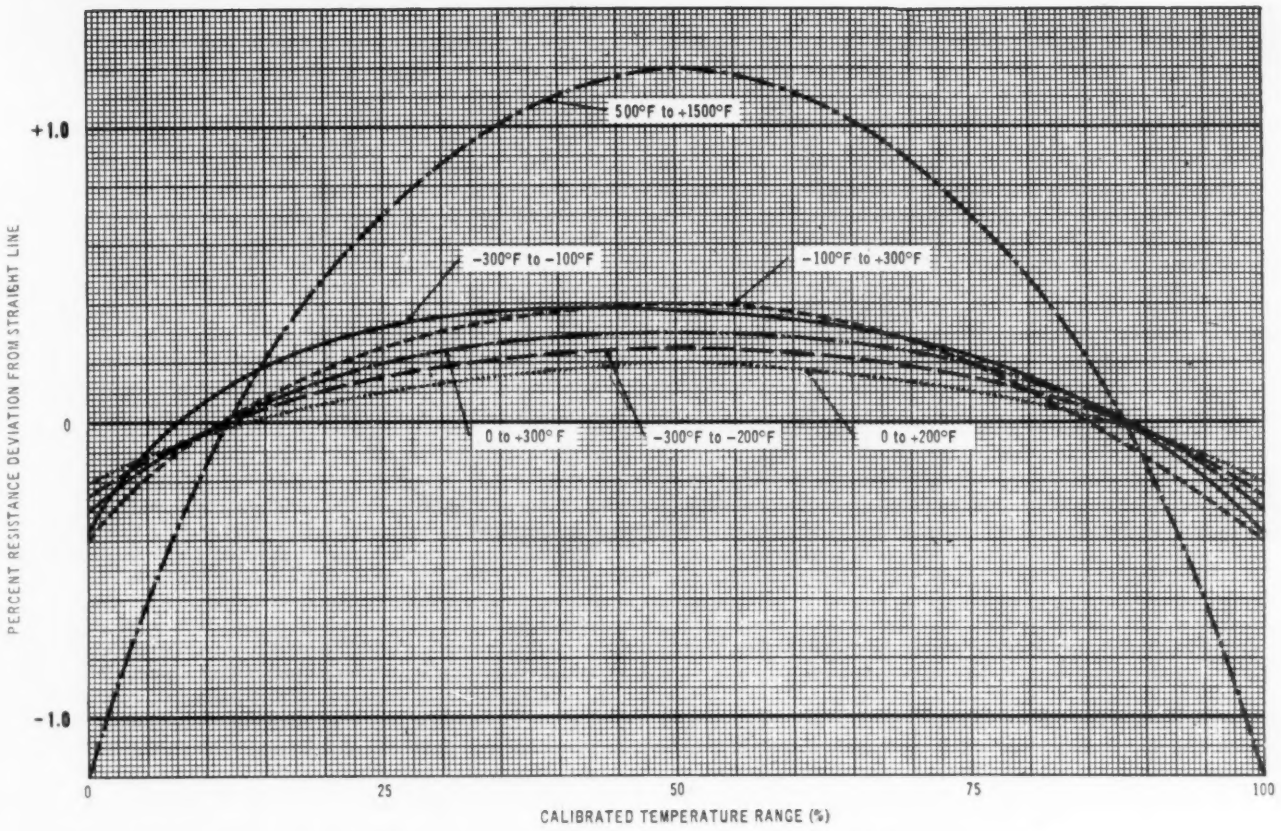

FIG. 1—Percentage deviation of the resistance of platinum wire from a straight line over various temperature ranges.

high performance aircraft. These instruments operate with accuracy and reliability under the severe conditions of vibration, shock, and acceleration encountered in these applications, and are ideally suited for the most critical temperature measurements. Additional features of Trans-Sonics platinum resistance thermometers can be summarized as follows:

- *Large Signal Output.* Resistance thermometers can control large enough signal outputs to make intermediate amplifiers unnecessary. This is particularly helpful in telemetry applications. With a d-c power source and passive elements such as resistors and telemetering commutators, output signals up to 5 volts are obtained.
- *Absolute Measurement.* The calibrated platinum thermometer has a resistance uniquely related to temperature, and thus becomes an *absolute* temperature measuring device. For this reason, installation is simpler and more dependable than that of a thermocouple temperature measuring system which requires a reference junction.
- *Versatility of Use.* Construction of the platinum resistance thermometer can be adapted for use with gases, liquids, and solids, and all such transducers can operate with either a-c or d-c excitation and circuitry.
- *Long Dependable Life.* Because platinum is an inert, noble metal, it is free from effects of contamination by foreign materials in most environments, and can be used indefinitely.
- *High Speed of Response.* Platinum resistance thermometers can be designed with low thermal inertia and a correspondingly high speed of response. This feature is particularly valuable in high-speed temperature control applications.
- *Well Established Standard.* The International Temperature Scale of 1948 uses platinum as the temperature standard over the range of –300 degrees F to +1165 degrees F (–185 degrees C to +630 degrees C).

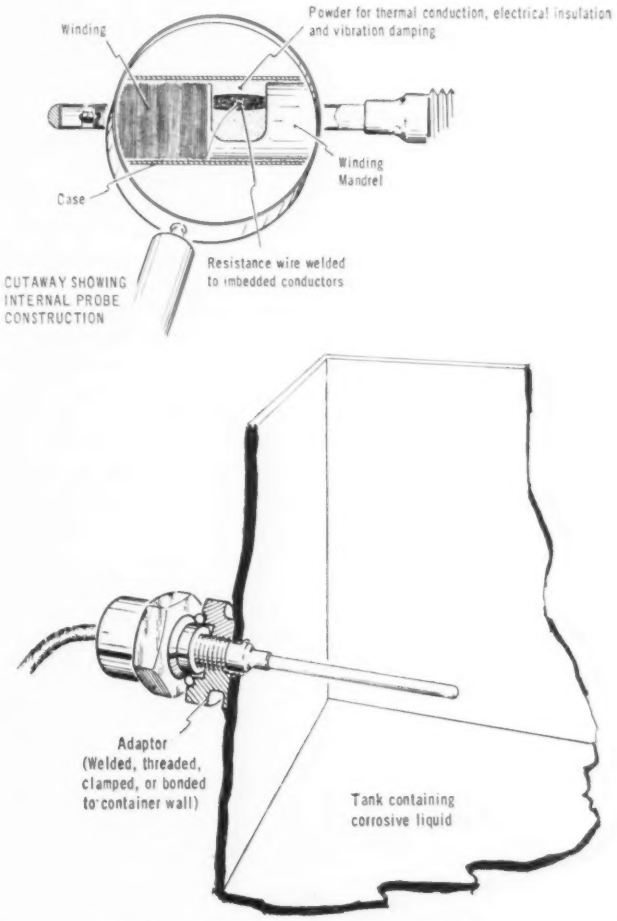
Winding
Powder for thermal conduction, electrical insulation and vibration damping
Winding Mandrel
Case
Resistance wire welded to imbedded conductors
CUTAWAY SHOWING INTERNAL PROBE CONSTRUCTION
Adaptor (Welded, threaded, clamped, or bonded to container wall)
Tank containing corrosive liquid

FIG. 4—Cutaway drawing of internal probe construction of bulb temperature pickup and typical application.

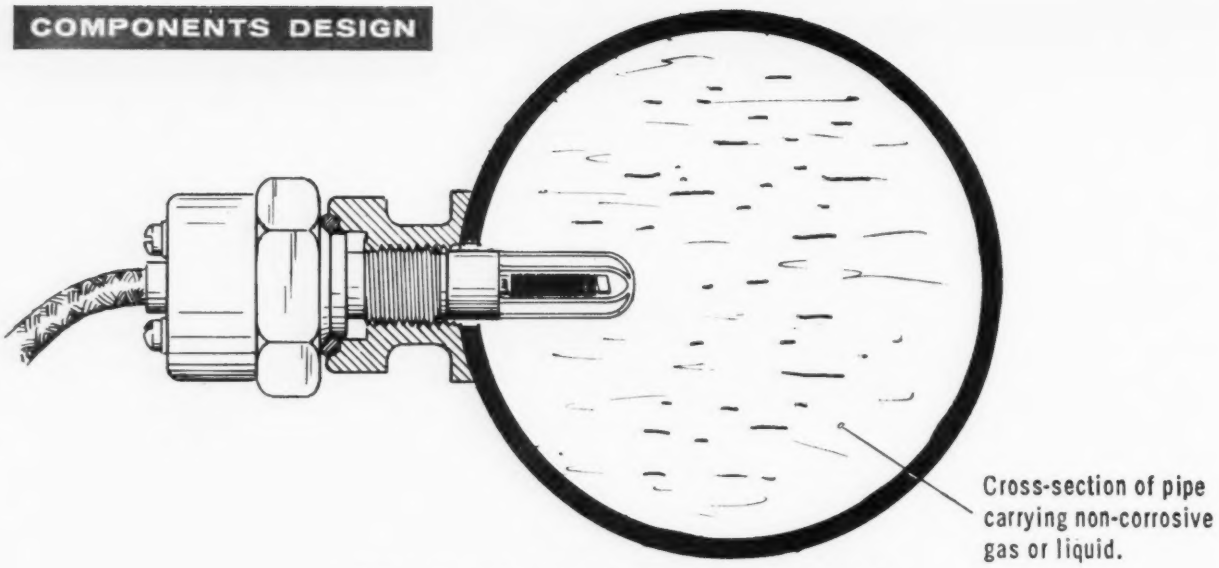

FIG. 5—Typical application for open temperature pickup.

III. Measurement of Gas, Liquid, and Surface Temperatures

One of the important requirements of a temperature sensing element is that its output be essentially a linear function of temperature over the required range. Figure 1 shows percentage deviation of the resistance of platinum wire from a straight line over various temperature ranges. It can be seen that platinum thermometers are highly linear over ranges of a few hundred degrees F, and are acceptably linear over ranges as great as 1000 degrees F. The platinum resistance characteristic is sufficiently linear to allow accurate interpolation between calibration points (maximum interpolation error, even for wide-range instruments, is under 0.25 percent).

For different temperature measuring applications, three basic types of resistance thermometers are available:

BULB TEMPERATURE PICKUP

The bulb temperature pickup, shown in Fig. 3, is designed for temperature sensing in corrosive liquids or gases. Figure 4 shows a cutaway of the internal probe construction with the resistance wire welded to the embedded conductors.

For utmost protection against destructive environments, a stainless steel tube is used to encase the platinum sensing element. The body of the pickup, including the mounting thread and nut, is also of stainless steel. The mounting nut is machined to seat against a metal O-ring to provide a pressure-tight seal against the vessel wall. The leads are teflon-covered and protected with stainless steel braiding. A unique design feature permits these leads to be easily removed from the body of the pickup. External leads can then be secured to the instrument terminals with the nut provided or by soft-soldering or silver-soldering directly to the terminals.

In a commutator circuit, the bulb pickup can deliver output voltages up to 5 volts. This voltage is sufficient for direct modulation of standard telemetering equipment without additional amplification. Maximum continuous current ratings for these instruments is 20 ma rms. Operating temperature range is from −400 degrees F to +1800 degrees F.

OPEN TEMPERATURE PICKUPS

Open temperature pickups are designed for high-speed temperature sensing in noncorrosive liquids and gases, as shown in Fig. 5. Two types are available:

- *Supported Winding:* This instrument, shown in Fig. 6a, has the platinum sensing element wound around a card structure which is surrounded by a stainless steel protective cage. Noncorrosive liquids or gases can easily pass through the open cage structure and contact the platinum directly, with resulting high speed of response. Temperature oper-

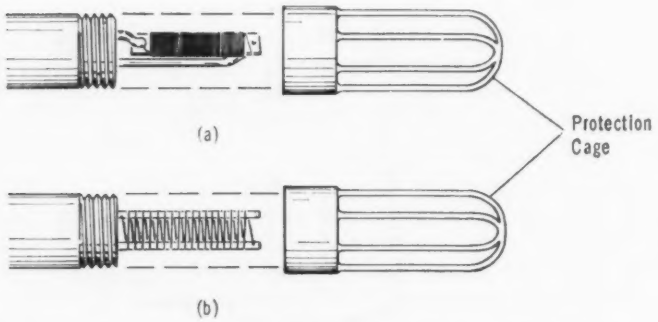

FIG. 6—Supported-winding (a) and open-grid (b) temperature pickups.

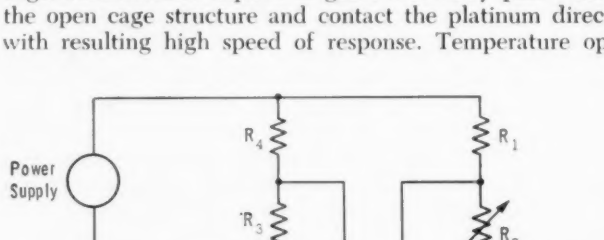

FIG. 8a—Conventional Wheatstone bridge circuit.

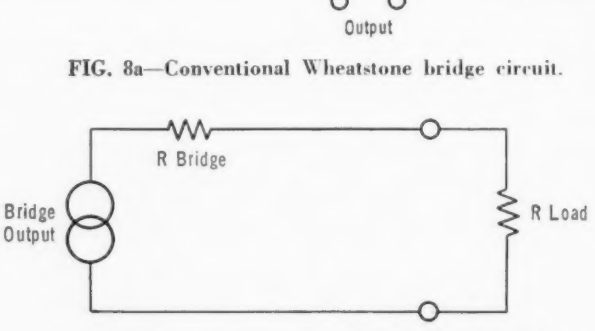

FIG. 8b—Thevenin equivalent of bridge circuit.

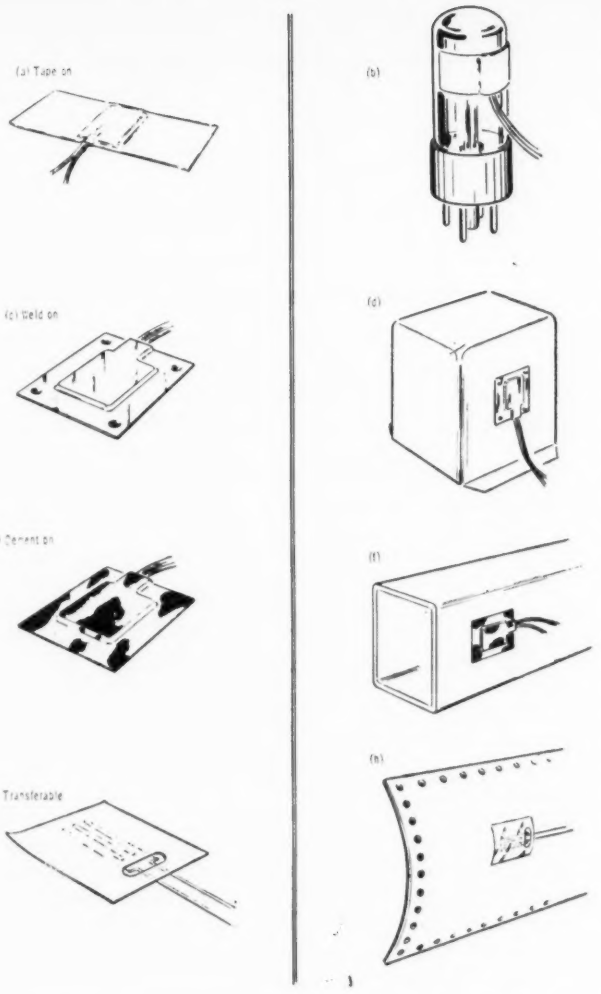

FIG. 7—Surface temperature pickups and their typical applications.

ating range for this type of pickup is from –400 degrees F to +750 degrees F. Time constant in agitated water is 50-200 milliseconds, and in air at 20 ft sec, is less than 2.5 seconds.

• *Open-Grid:* The open-grid pickup, shown in Fig. 6b, has the platinum wire wound around two ceramic-covered posts. The exposed open-grid wires have an extremely fast thermal response. Temperature operating range is from –400 degrees F to +1000 degrees F. Time constant in air with mass flow of 15 lbs/ft²/sec is approximately 750 milliseconds.

The entire body of both the supported-winding and open-grid pickups is stainless steel. Mounting nuts for these units are machined to seat against a metal O-ring to provide a pressure-tight seal against the vessel wall. Both types of instruments have teflon-covered leads protected by a stainless steel braided shielding. As in the bulb temperature pickup, the leads are removable for versatility of use.

When used in a commutator circuit, open temperature pickups can deliver up to 5 volts without additional amplification. This voltage is sufficient for direct modulation of standard telemetering equipment. Maximum continuous current ratings for these instruments is 20 ma rms.

SURFACE TEMPERATURE RESISTORS

Surface temperature resistors are designed for direct mounting on different types of surfaces. As shown in Fig. 7, four types of surface resistors are available:

• *Tape-On:* The Tape-On surface temperature resistor, shown in Fig. 7a, consists of platinum wire, 0.001 inch diameter, wound on a thin card. The card is then wrapped in extremely thin tape to protect the platinum wire. The protected card can be applied to any surface by simply taping it in place, as shown in Fig. 7b. Operating range for this resistor is from –320 degrees F to +550 degrees F.

• *Weld-On:* This type of surface resistor (Fig. 7c) consists of a thin platinum winding, inorganically insulated. The entire unit is housed in a thin stainless steel cover which can be spot-welded to any flat metallic surface, as shown in Fig. 7d.

The Weld-On resistor measures surface temperatures in the range from –400 degrees F to +1500 degrees F.

• *Cement-On*: This resistor, shown in Fig. 7e, has the same construction as the Weld-On resistor, with the exception that a stainless steel wire mesh is used for the die-formed cover. The Cement-On resistor has a temperature range of from –400 degrees F to +1500 degrees F and is designed for cementing to any metallic or nonmetallic surface. (Fig. 7f).

• *Surface Transferable Resistors*: The Surface Transferable Resistor (Fig. 7g) consists of a platinum wire grid supported by a ceramic matrix. During shipment, the unit is mounted on a thin paper card. Installation of this pickup consists of first applying a layer of ceramic cement to the desired surface and to the body of the pickup. The pickup is then placed, grid down, on the surface and allowed to dry. Finally, the protective paper card is removed, leaving the resistor bonded to the surface, encapsulated in the ceramic coating. No organic material remains after installation.

One of the main applications for this instrument is measurement of temperatures up to 2000 degrees F on flat, curved, or irregular surfaces (Fig. 7h).

IV. Circuitry

GENERAL BRIDGE CIRCUITRY

A conventional Wheatstone bridge forms the basis of most resistance thermometry circuitry (Fig. 8a). Occasionally, it is desired to know the output impedance of the bridge. Since the bridge is operated near the null, there is essentially no current flow through the bridge load. As an approximation, the power supply resistance can thus be neglected in determining the open circuit bridge impedance and may be determined from the equation given below.

$$R_{\text{bridge}} = \frac{R_1 R_2}{R_1 + R_2} + \frac{R_3 R_4}{R_3 + R_4}$$

The Thevenin equivalent for the bridge circuit is shown in Fig. 8b.

It should be noted that the bridge and load impedance form a voltage divider. In most practical applications, however, the load is the input to a vacuum tube having an input impedance of 500K or higher. Since the bridge impedance is ordinarily 1K or lower, the voltage divider action can be neglected.

When the output of the bridge is used to drive a low impedance load, such as a transistor, galvanometer, or magnetic amplifier, the bridge impedance should be included in the calculations since its value influences maximum current obtainable from the resistance thermometry circuit.

SELF-HEATING OF RESISTANCE THERMOMETER

The maximum current that may be used in a resistance

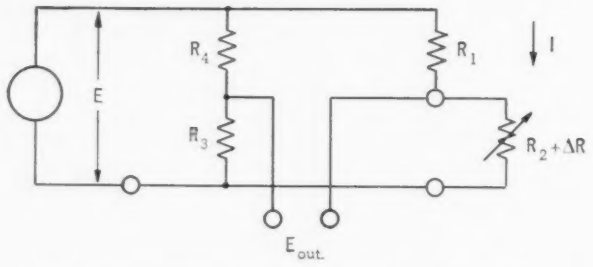

FIG. 9—Two branches of resistance bridge circuit.

thermometer is limited by the effect of I^2R heating caused by the excitation current flowing through the sensing element. This heating may vary from one application to another, depending on ability of the environment to carry away heat generated in the probe. As a general rule, currents as large as 20 ma rms do not cause significant self-heating errors. For example, an open type construction sensing element with 450 ohms of platinum shows an off-set in temperature when immersed in liquid oxygen of only 0.2 degrees F for an excitation current of 25 ma rms.

In some applications, exciting the transducer with currents larger than 20 ma rms may be desirable in order to obtain large output voltages. In these cases any error due to large excitation currents can be avoided by using time-sharing techniques. For example, the transducer described above shows negligible self-heating when excited with peak currents of 100 ma in a commutator circuit with a duty cycle of 1/60. The rms current under this condition is only 1.6 ma. Since thermal time constant is long compared to excitation period, effective heating current in the transducer is related to the rms current, not peak current.

HIGH IMPEDANCE LOAD, CONTINOUS OPERATION

Design of resistance thermometer bridge circuits can be simplified if the resistance bridge is considered as two voltage dividers as shown in Fig. 9. In this figure, R_1 and R_2 make up the variable (or active) voltage divider, and R_3 and R_4 constitute the reference voltage divider. If it is desired to design a bridge to match a specific resistance thermometer, where resistance at the low end of the temperature range and resistance change over the temperature range are known, the circuit can be analyzed in the following way.

Resistance thermometers can be excited with a supply voltage, E, which may be either a-c or d-c. Inductance of the platinum sensing element is negligible at common a-c supply frequencies. The d-c or rms a-c current through the resistance thermometer usually ranges from 2.5 to 20 ma, depending upon the application.

Minimum total resistance of the active side of the bridge is

$$R_{\text{total}} = R_1 + R_2 = \frac{E}{I}$$

where I is the current through the active leg of the bridge, and R_2 is the platinum resistance at the low end of the resistance thermometer temperature range. By definition, ΔR is change in resistance of the thermometer over the calibrated temperature range. Bridge output voltage is thus

$$\Delta E = \left(\frac{R_2 + \Delta R}{R_1 + R_2 + \Delta R} \right) E - \left(\frac{R_2}{R_1 + R_2} \right) E$$

over the temperature range of the resistance thermometer.

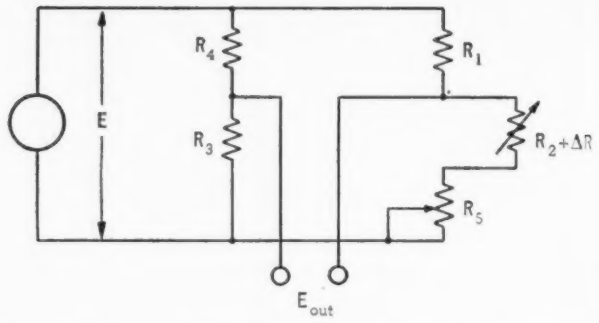

FIG. 10—Resistance bridge with series trimming resistance in active leg.

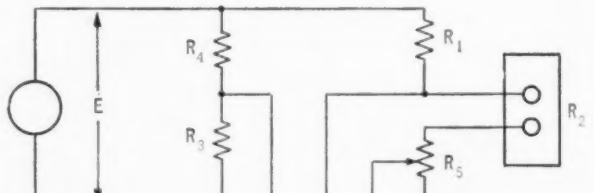

FIG. 11—Use of decade box to simulate thermometer during bridge calibration.

Thermometer resistance, R_2, has a ±5 percent or ±10 percent tolerance from one thermometer to another. It is thus convenient to insert a variable resistor in series with R_2, as shown in Fig. 10, to aid in adjusting the circuit for a null. The resistance R_5 should be chosen to allow balance of the bridge for all values of the resistance thermometer within the operating range. As a result, resistance thermometers can be interchanged without circuit redesign. Resistance R_5 should thus have a maximum value of twice the maximum tolerance.

The most convenient method for adjusting the resistance thermometer bridge is to insert a decade resistance box in place of the resistance thermometer, as shown in Fig. 11. The resistance box is adjusted to the precise resistance value given on the thermometer calibration certificate, at the point where bridge null is desired (usually the low-end point or the center point). Then R_5 is adjusted for $E_{out} = 0$. The bridge is now balanced and ready for attachment of the resistance thermometer in place of the resistance box.

LOW IMPEDANCE LOAD, CONTINUOUS OPERATION

Driving a low impedance load, such as a galvanometer,

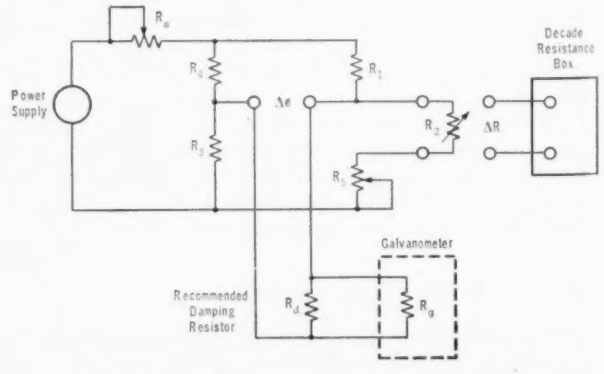

FIG. 12—Galvanometer bridge circuit.

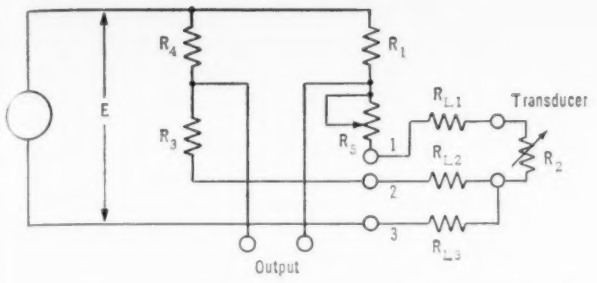

FIG. 13—Wheatstone bridge with Siemens' three-lead compensation.

with a resistance thermometer bridge is often desired. Because of current drain in the load, a calibration procedure that allows for this effect should be used.

To complete the resistance thermometer bridge circuit, values for R_3 and R_4 must be calculated. As stated previously, R_3 and R_4 comprise the bridge reference voltage divider. This network supplies a constant voltage to buck out the voltage from the active leg of the bridge, usually at minimum temperature ($\Delta E = O$). This can be accomplished by selecting R_3 and R_4 to have the same ratio as R_2 and R_1 at minimum temperature.

The circuit for driving a low impedance load with a resistance bridge is shown in Fig. 12. The procedure for a precise calibration of this circuit is as follows. This procedure has the advantage of transferring the 5-point platinum resistance calibration directly to the galvanometer output scale.

- Replace platinum resistance element, R_2, with a precise decade resistance box. Set resistance box to the value given on the thermometer calibration certificate at the point where the bridge null is desired. The null is usually at the low end of the thermometer range, and this condition will be assumed in the following procedure.
- Adjust R_5 for a null.
- Adjust decade box to resistance corresponding to full range resistance as determined from calibration certificate.
- Adjust R_s to obtain desired galvanometer deflection at full scale.
- The whole circuit, including the galvanometer, may then be calibrated by setting the decade box to the resistance corresponding to 25 percent, 50 percent and 75 percent of full scale as taken from the calibration certificate.

THREE-WIRE CIRCUIT

Resistance of the lead wires, and their change in resistance with temperature, is small when compared to resistance of the thermometer itself, and its resistance change. For this reason, in most standard applications, error introduced into temperature measurements can be neglected. Thus, only 2 lead wires are necessary from the thermometer to the indicating or control instruments.

In cases where high-accuracy temperature measurements are required, or where long leads are used that may experience varying temperatures, the Siemens Method is a very satisfactory means of lead temperature compensation.

Figure 13 gives the wiring for a Wheatstone bridge and resistance thermometer with Siemens three-lead compensation.

The basic requirements for the Siemens compensated circuit are:

The two leads, R_{L1} and R_{L2}, should have the same resistance and the same temperature coefficient of resistivity.

$$R_{L1} = R_{L2}$$

$R_3 = R_2$ (then $R_1 = R_4$ if it is desired to balance the bridge). When the bridge is balanced, the following relation applies:

$$\frac{R_2 + R_{L1}}{R_1} = \frac{R_3 + R_{L2}}{R_4}$$

Since R_1 is constructed equal to R_4, and $R_{L1} = R_{L2}$, then $R_2 = R_3$. Hence measured resistance is independent of resistance of the lead wires. As a result of this temperature compensation, temperature information can be transmitted over long distances without a time lag and without a radio link. Leads on Trans-Sonics temperature pickups have a sufficiently low resistance that the three-wire circuit need not be carried all the way up to the sensing element.

V. Applications

TELEMETRY CIRCUIT WITH COMMUTATION

An important application for platinum resistance thermometry is in telemetry. Physical ruggedness of the units allows them to withstand high acceleration in guided missiles and high-speed aircraft, and the unamplified bridge signal output of 5 volts (full scale) is suitable for direct modulation of telemetering equipment.

Best use is made of a telemetering channel if several transducers use it on a time-sharing basis. A simple single-pole commutation scheme is shown in Fig. 14. Each resistance thermometer has its own series trimming potentiometer. Total resistance of each of the active bridge arms is thus standardized, usually to a value of 500 ohms at the minimum resistance (minimum temperature) point. Figure 15 gives resistance R_1 vs bridge output E_{out} for different excitation voltages commonly used in resistance thermometry commutator circuits. R_2 in this case is 500 ohms at minimum temperature.

There are several advantages of using commutation with resistance thermometers. Power supply, bridge circuit, and telemetry channel can be shared by 30 or more transducers. Total power demand is approximately the same as that of a single continuously excited transducer. Furthermore, reduced duty-cycle of a time-sharing system allows a high excitation current to be fed to the platinum resistance elements for a brief interval, without the self-heating problem arising. Thus resistance thermometers can be driven to peak voltage outputs 30 or more times their allowable continuous outputs.

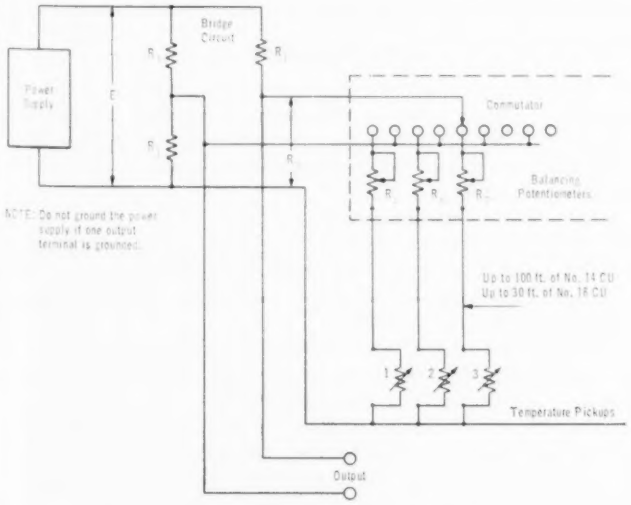
Bridge Circuit
Power Supply
E
Commutator
Balancing Potentiometers
NOTE: Do not ground the power supply if one output terminal is grounded.
Up to 100 ft. of No. 14 CU
Up to 30 ft. of No. 16 CU
Temperature Pickups
Output

FIG. 14—Temperature pickup commutator circuit.

CONTROL CIRCUITS. ABSOLUTE CONTROL.

The platinum wire resistance thermometer is conveniently used in absolute temperature control applications. Figure

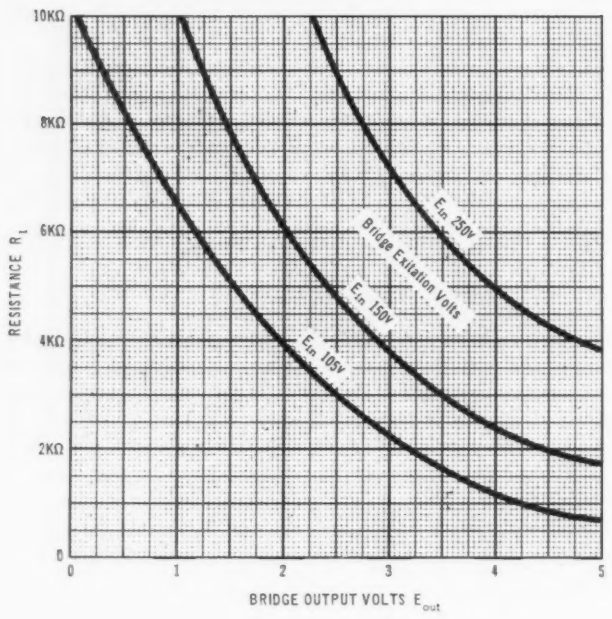

FIG. 15—Resistance R_1 vs bridge output E_{out} for different excitation voltages.

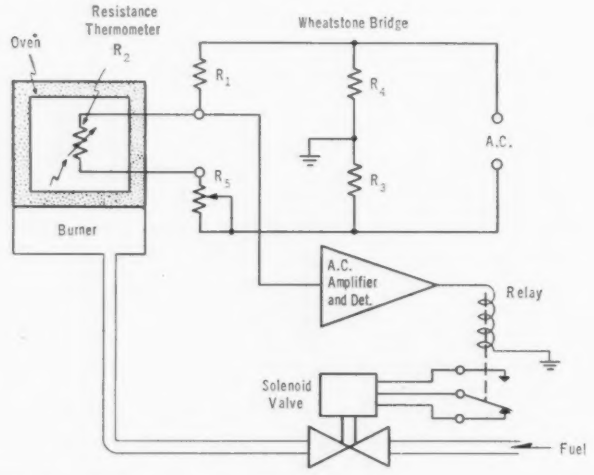

FIG. 16—Typical oven regulation set-up.

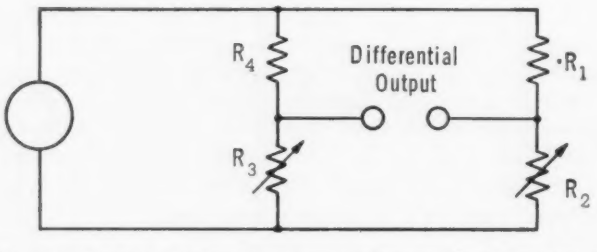

FIG. 17—Circuit diagram for two resistance thermometers in differential control application.

16 shows a typical oven temperature regulation set up. The degree of temperature regulation depends on thermal time constant of the resistance thermometer, loop gain of the amplifier, capacity of the heating element, and thermal mass of oven. A lead or anticipation network can be inserted in the amplifier to compensate for the time lag of the heating element (oven) and the resistance thermometer. Even without these added refinements, this temperature control system is capable of high accuracy; better than ±0.1 degree F in standard systems.

The operation of the system is as follows:

- The resistance thermometer is mounted so that the sensing element is inside the oven. Figure 16 shows the circuit. The bridge is usually excited with an a-c voltage.
- The output of the bridge circuit is then fed into an amplifier. Quite a variety of amplifiers are suitable for this application. Magnetic amplifiers are particularly satisfactory because they are rugged and dependable, and have a long and maintenance-free life. After amplification, the a-c bridge output signal normally goes to a phase detector and filter, and serves to actuate a d-c single-throw (on-off) relay. If 2-directional temperature control is desired, using both hot and cold temperature inputs to the chamber, the phase-sensitive detector can be used to drive a double-throw relay. Position of the relay depends upon whether the phase of the bridge output signal is 0 degree or 180 degrees. For such bilateral control, the bridge null must occur when the chamber is precisely at the "set" temperature of the controller.
- The relay operates a solenoid valve which controls the fuel injection into the oven burner. This is an "on-off" type control, but is satisfactory in many applications. For closer temperature control, the fuel valve can be of the proportional type. Size of the valve opening would be proportional to the magnitude of error signal. Often a rate network is used in this proportional-type temperature control system, so that large transients imposed on the control system can be sensed and the valve can be opened wider to maintain constant oven temperature. Such a transient is generated when the oven door is opened and a fresh load of material is put into the oven for processing.

Differential Control: Two resistance thermometers can be inserted in adjacent arms of a bridge to indicate temperature differentials, as shown in Fig. 17. This feature is applicable in very accurate calorimetric work and jet engine compressor controls where it is desired to observe temperature differentials.

For more information on platinum resistance thermometry:

Circle No. 56 on Inquiry Card

Pulse to Shaft-Position Converter

Electromechanical shaft positioning device gives a 2° increment rotation when a d-c pulse is applied across the terminals. With output torque as high as 14 oz-in, stepping output is as rapid as 60 steps per second and is unlimited in either direction.

Input power requirement is one amp at 28 volts, which can be applied for as short a time as 10 milliseconds per step of output. A precision potentiometer may be incorporated within the housing for a divided voltage output proportional to shaft position.

Valuable for use as a d-c pulse-to-analog shaft positioner in computers, sequence switching, algebraic counting, and remote shaft positioning, the mechanism of the Rotostepper consists of a gear wheel rotated by two solenoid actuated ratchet pawls. Between impulses, the mechanism is locked in accurately located shaft positions by a spring-loaded detent. G. M. Giannini Co., Pasadena, Calif.

Circle No. 185 on Inquiry Card

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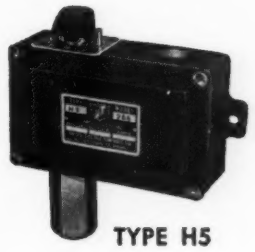
External Adjustment & Calibration
on
PRESSURE & VACUUM CONTROLS H5 H12



TYPE H5

TYPE H12

UNITED ELECTRIC designed these controls for industrial applications where outside adjustment and calibration are important factors. Types H5 and H12 accurately and sensitively control liquid level alarms and air gas pressures. The type H5 (minimum 2 psi differential) controls up to a maximum of 500 psi, and the type H12 (minimum 3" wc differential) up to 180 psi. Uncalibrated, internally adjusted versions of these controls are available as type J7 and type J6 respectively.

Switch Differential	H5 — Uniform on-off differential, fixed from 2 psi to 30 psi. H12 — Uniform on-off differential, fixed from 3" wc to 2 psi.
Switch Ratings	15 amps. at 115 or 230 volts AC, also 20 amps. or DC switches on specification.
Switch Types	N.O., N.C., or Double Throw, no neutral position.
Size & Weight	H5 — 5⅛" x 4⅞" x 1½" . . . weighs approx. 1 lb. H12 — ¾" x 2¾" x 5" weighs approx. 1 lb. 6 oz.
Electrical Connection	Conduit opening in enclosure — ⅞" O.D. Internally-located terminal block.
Enclosure	Die-cast aluminum case with black wrinkle finish.
Mounting	H5 — Directly, by ¼" female NPT on bellows housing; or surface mounted by mounting ears on each end of case. H12 — Directly, by ¼" female NPT on bellows housing.
Bellows	H5 — Spring loaded, seamless brass, stainless steel or monel. H12 — Spring loaded, seamless brass bellows.
Pressure Connections	¼" female NPT.

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STAFF COLUMNIST

MARTIN E. KAGAN
Vice President of
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MEET ME AT THE FAIR

One goes to the Brussels Fair as if to a battle ground; for it has become just that in the gigantic East-West conflict. This was not the intentions of the organizers of this enterprise. They wanted "to make an assessment in a concrete form, setting out at all levels of human activity the situation in the world today" and "to infuse a FIGURE of HUMANISM into this world, in a word, to suggest in a practical and realistic manner the means by which this ideal may be attained."

The beauty, excitement and context of the fair do much credit to the planners of the exhibition. On the whole it is a colorful and well arrayed display of the results of human endeavor in the past half century. The central Atomium tower emphasizes the technological surge of our modern life; the eight supranational exhibits such as the United Nations, Red Cross and similar organizations, signify the social strivings of the past few generations.

Fifty national exhibits are attempting with varying degrees of success to show their contributions to the making of a new world. Unfortunately, we must count the American Pavilion as one of the lesser successes. As a nation, The United States comes off fairly well. It is well represented in the International Science Exhibition. The Atomium displays on atomic energy bear the American stamp with American companies well in front in the various fields of nuclear development among the Western nations. Throughout the Fair there is a generous sprinkling of individual exhibits, bearing American colors but international in nature—exhibits such as IBM, IT&T, etc., all outstanding and interesting.

It is the American exhibit, in particular, and probably by contrast, which many observers, American and foreign, find lacking. Apparently depending on the other exhibits, we have left the main American pavilion almost bare. It is almost as though we are too bashful or modest to boast about ourselves. To the average European tourist, who covers the Fair in a limited time and expects to find the face of America in the national exhibit, it is a great disappointment. To the American tourist it is a heartbreak.

What are the technological highlights at the Fair? The most fascinating exhibit in the American Pavilion is Walt Disney's Circarama. This is a new development in the motion picture field. A 360-degree motion picture screen is run by eleven synchronized motion picture projectors and gives the viewer standing within the circle an uninterrupted panoramic scene. Several other items in the American Pavilion are also noteworthy: a complete unmanned oil refinery, fully automated, detects and corrects errors; a data logger, records all production information. In a display of computer intricacy, IBM's RAMCA gives the major historical events of any year between 4 B.C. and 1958 in any one of ten languages chosen by the visitor in less than a second. In the nuclear section there are demonstrations of the effect of irradiation on the preservation of the freshness of food, radioisotopes as aids in agriculture, and the use of a radiographic camera. But the bulk of U.S. scientific knowledge is displayed at the International Hall of Science. There, in four categories, The Atom, The Molecule, The Crystal and The Living Cell, the U.S. demonstrates its progress in the fields of solar energy, particle accelerators, recombination of atoms, photosynthesis and similar areas.

Of the other national exhibits the material displayed by the Soviet Union is the most impressive. Their press at the show frankly states that each country has taken part in the Fair with a view to making propaganda of its achievements. And the Soviet Union makes the most of it. The main floor of their pavilion features an array of heavy machinery operating during the visiting hours. The first two sputniks are centrally displayed in full scale and with the complete housing for Laika. In the field of atomic energy, the Soviet Union features a model of a 10 Bev accelerator, which they claim is the world's most powerful. In the wings one finds a large number of instruments, optical devices, computers—all surprisingly streamlined in appearance.

Technically, the best coordinated of the national exhibits is the Czechoslovakian. At the entrance of its exhibit is a gigantic 170-ton fly wheel for the Kaplan turbine, a new concept in hydro-electric power plant turbines according to the Czechs. The Vltava Cascade, the site of the dam and hydro electric power plant run by this fly wheel and turbine is here in a scale model. There is also a model of the first Czech atomic power plant which has an output of 150 MW. And amidst all this is a working Betatron of 15 Mev designed for medical research purposes. Czechoslovakia is one of the few countries capable of producing complete equipment of factories, power plants and refineries; displays of giant machine tools point up this fact. Modern techniques, such as polarography, officially claimed to have originated in Czechoslovakia by Prof. Jaroslav Heyrovsky, are also displayed.

Britain's exhibit is a masterful synthesis of the old and the new. After a compulsory tour through the Hall of Tradition (the visitor must enter the Pavilion through this hall) one enters the Hall of Technology and is confronted with a large diorama of the Scottish coast at Duonreay with its spherical atomic reactor. A model of ZETA, the first ever shown to the public, climaxes a series of exhibits showing some recent advances in medicine, radar and radio-astronomy. The Jodrell Bank Radio-Telescopes and the Mullard Interferometer are presented against a background of night sky. Outside one finds a panel listing British inventions—a very impressive compilation. Various aspects of Britain's contribution to world progress, advances in the fields of engineering, textiles, consumer goods and services are well presented in the British Industries Pavilion, the only non-Belgian exhibit completely financed by private enterprise.

While the Brussels Exhibition is focusing attention on the contributions of many countries—a full scale installation showing how the sea was pushed back from the coast of the Netherlands, a rare earth study in the French exhibit, an artistic panel display showing Italy as the cradle of inventions—one should not forget that the Fair is primarily Belgian. To that end Belgium has constructed several dozen buildings dealing with various present day Belgian industries and commerce. One finds them as illuminating and entertaining as any of the national pavilions. END

For Your 3-Ring Binder

NEW DATA SHEETS

More and more manufacturers are issuing prepunched design data and spec sheets on their new components. Each month in this section we shall report those ranging in size from 1 to 4 pages that belong in your data file. Catalogues and design manuals larger than 4 pages will still be reported as "Worth Filing" items. For your free copy of the data sheets listed on this page, circle the appropriate number of the item on the Inquiry Card.

• Vacuum Induction Melting Furnaces. Furnaces are capable of handling molds up to 27 inches high and 16 inches in diameter, and allow pouring under vacuum in pressure range of 1 to 5 microns. F. J. Stokes Corporation, Philadelphia 20, Penn. Circle 241.

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• Size 8 Servomotor. 115-volt, 400-cycle servomotor has low rotor inertia—0.2 gm.-cm^2, and comparatively high stall torque—0.33 oz-in. Helipot Corporation, Newport Beach, California. Circle 236.

• Recording Annunciator. Accurately records without complicated decoding off-normal and on-off operations, future downtime and maintenance in various industries concerned with temperature, pressure, flow and levels problems. Panellit Inc., Skokie, Illinois. Circle 237.

• Single Element Push Buttons. For individual or flash panel mounting in non-oiltight standard duty applications, button contains momentary double break silver-to-silver contacts rated at 3 amps, 120 volts, a-c. Ward Leonard Electric Co., Mount Vernon, N.Y. Circle 238.

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• Yoke Winder. High production multiple deflection yoke winder, with unique oscillating winding motion which places wire in exact position on winding form to produce repetitively accurate windings, virtually eliminates rejects caused by insulation fractures during pressing operation by form winding. George Stevens Mfg. Co. Inc., Chicago 46, Illinois. Circle 240.

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• Solvent and Detergent. Isostrip 701.—Fast acting stripping solvent for the recovery of valuable parts, coated, cast or molded in epoxy or polyester compounds. Isoterge 1405.—Solvent-based non-flammable cleanup detergent with minimal toxicity for removal of uncured epoxy, polyester and similar resins. Isochem Resins Corp., Providence 9, R.I. Circle 243.

• Butterfly Valves. 50 lb standard tight-closing, rubber-seated, compact, butterfly valves for tight-closing and throttling applications. Builders-Providence Inc., Prov. 1, R.I., Circle 244.

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• Precision Wire-Wound Resistors. Fully encapsulated precision wire-wound resistors have tolerances in the vicinity of 0.01%; unusual stability; extremely low temperature coefficients; axial, radial, or solder lug leads. Ultronix Inc., San Mateo, California. Circle 246.

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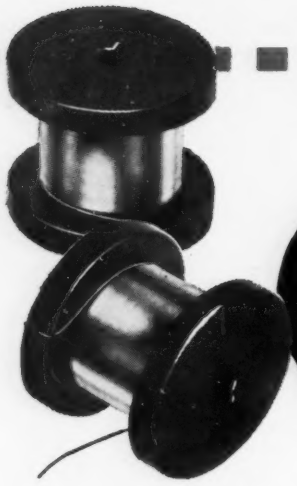

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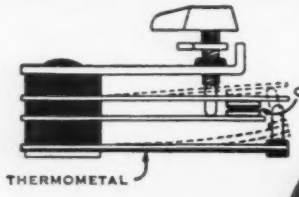

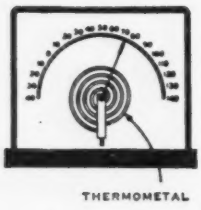

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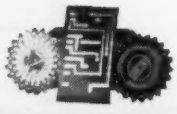

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